ISO 26262 : 2011

Rustam Rakhimov
(DMS Lab)

Introduction

- Adaptation of IEC 61508 to road vehicles
- Influenced by ISO 16949 Quality Management System
- The first comprehensive standard that addresses safety related automotive systems comprised of electrical, electronic, and software elements that provide safety-related functions
- It intends to address the following important challenges in today's road vehicle technologies:
  - The safety of new E/E and Software functionality in vehicles
  - The trend of increasing complexity, software content, and mechatronics implementation
  - The risk from both systematic failure and random hardware failure

Escalating Complexity Over Time

Space Shuttle
~500K Lines of Code

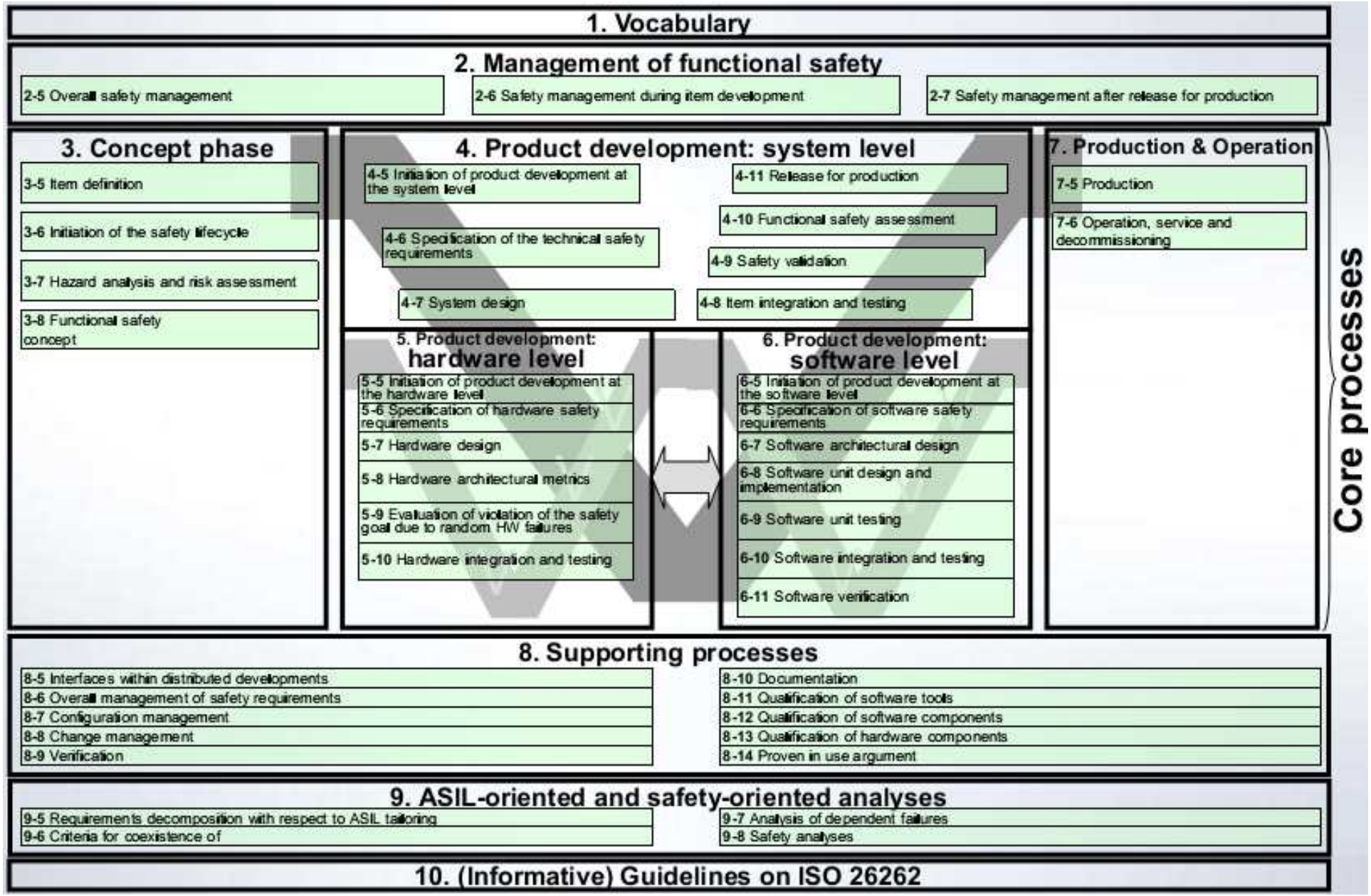
Boeing 777
~3M Lines of Code

Modern Automobile
100M Lines of Code
Up to 100 ECUs

ISO 26262

- An adaptation of IEC 61508 to fit specific needs of the automotive industry
- Provides guidance to avoid risk in creating safety-critical systems
- Regulates critical testing processes

General Structure of ISO 26262



Scope and Versions

- Conducted in June-July 2011, based on DSI draft published in 2009.
- Final standard (FDIS) was published in November 2011.
- Future discussions should be based on the FDIS version of the standard.
- Review Focus— Understand how well can the standard provide safety assurance for the complex software-intensive automotive electronics and electrical systems?

The ISO 26262 product lifecycle

- ISO 26262 is based on the concept of a *safety lifecycle*, shown in Figure 1, which consists of 6 phases: management, development, production, operation, service, and decommission. The goal of the standard is to maximize product safety by requiring specific steps to be taken during each of the phases. This ensures that safety is taken into consideration from the earliest conception of a vehicle to the point when the vehicle is retired from use. This document focuses primarily on the development phase, since this is the step in which embedded software is designed, developed, and validated.

ASIL - Automotive Safety Integrity Level

- The ISO 26262 automotive safety integrity levels (ASILs) are A, B, C, and D, where ASIL level A represents the least amount of risk and level D represents the most.

The ASIL for each component in a system is determined by three factors:

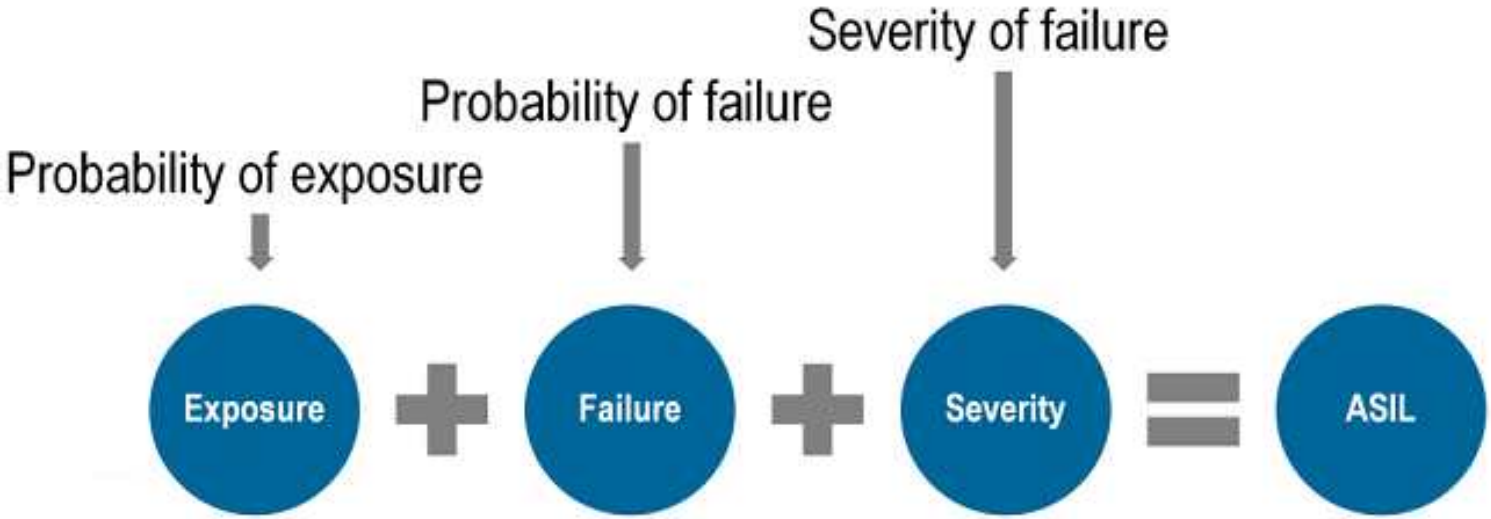
- **Severity** - is a measure of the health consequences of an event. There are four classes of severity, ranging from no injuries to life-threatening injuries.

- **Probability** - is the likelihood of the conditions under which a particular failure would result in a safety hazard. The probability of each condition is ranked on 5 point scale ranging from incredible to highly probable. For example, a failure of the headlights would result in a hazard when driving at night, when raining, or during other conditions which result in poor visibility — which would be considered highly probable due to the regular occurrence of these conditions.

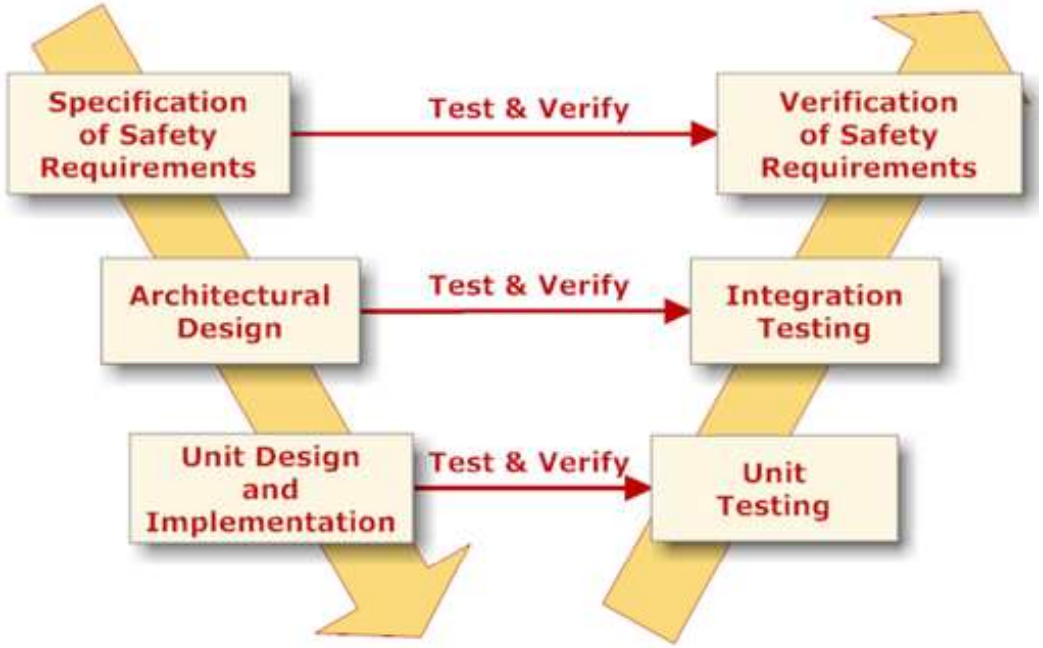
- **Controllability** - is a measure of the probability that harm can be avoided when a hazardous condition occurs, either due to actions by the driver, or by external measures. If the brakes fail to engage when the brake pedal is pressed, for example, the driver could use the emergency brake instead. The controllability of a hazardous situation is ranked on a four point scale from controllable in general to difficult to control or uncontrollable.

What is the Automotive Safety Integrity Level (ASIL)?

- Automotive-specific approach for assigning risk levels

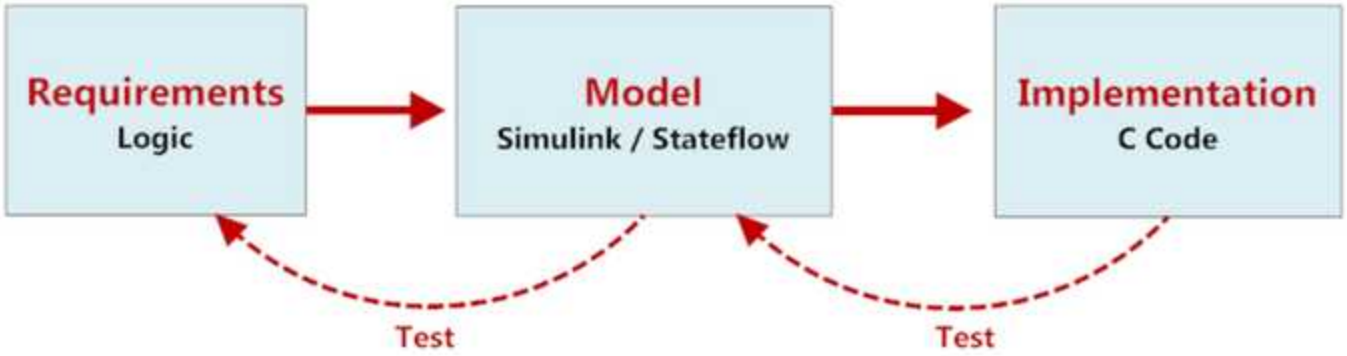


V Model



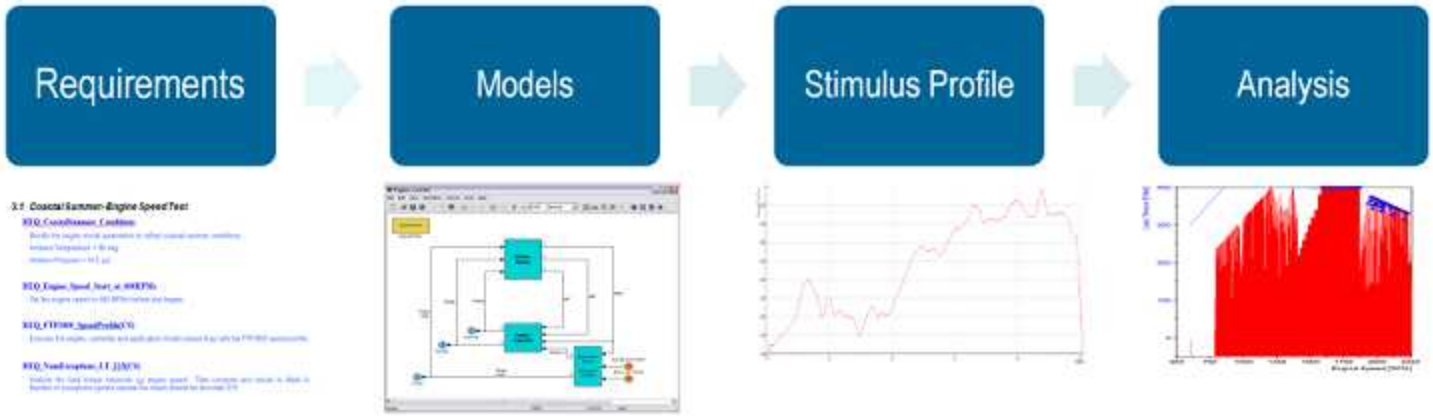
- The software development phase in ISO 26262 is subdivided into sub-phases according to a V-Model, as shown in Figure 3. The "V" shape is due to the fact that the testing and verification steps are performed in reverse order from design and implementation. Reactis can be used during each of the testing and verification steps.

Model-Based Design



- the value and importance of the model-based engineering paradigm is emphasized in Annex B of ISO 26262-6

Embedded Software Development Process
Model to Model Testing



Parts of ISO 26262

- Part 1 : Vocabulary
- Part 2 : Management of Functional Safety
- Part 3 : Concept phase
- Part 4 : Product Development: System Level
- Part 5 : Product Development: Hardware Level
- Part 6 : Product Development: Software Level
- Part 7 : Production and Operation
- Part 8 : Supporting Processes
- Part 9 : ASIL-oriented and Safety-oriented Analyses
- Part 10 : Guidelines on ISO 26262

This Presentation Is Divided into two Parts

- Overview for Each Parts of ISO 26262
- Detail Study of ISO 26262

Overview for Each Parts of ISO 26262

Part 2
Management of Functional Safety

- General Safety Management:
  - ISO 26262 assumes that the company has a defined, implemented and active QM system:
    - Safety Culture, Communication, Qualification of Employees

- Specific Safety Management during development:
  - ISO 26262 requires a Safety Manager (e.g. Project Leader)
    - to control safety activities
    - to develop a safety plan
    - to confirmation measures based on the safety plan
      - Safety reviews, safety audits or safety assessments

Part 3
Concept Phase

- It starts with the Item definition:
  - System or array of systems to implement a function at the vehicle level to which ISO 26262 is applied:
    - Specify the use and functionality
    - Specify non-functional requirements like operating conditions, laws and standards to follow

- Based on the item definition, the Hazard Analysis and Risk Assessment is done:
  - Goal of the risk assessment is:
    - to assess the item risk
    - to compare it to a public acceptable tolerable risk
    - to define measures to reduce this risk
  - The risk reducing measures are usually called Safety Integrity Level
    - Automotive Safety Integrity Level - ASIL

Part 3
Concept Phase

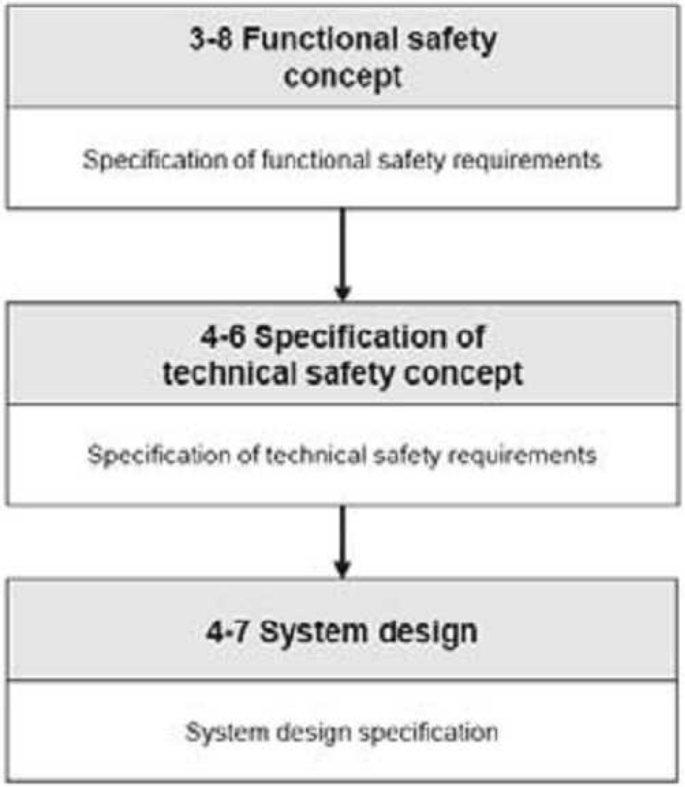
- Hazard Analysis and Risk Assessment in practice:
  - Identify operation states and driving situations of the item where th ere is a potential for hazards that are caused by this item
  - Determine the potential error cases and misbehaviors by incorporati ng system FMEA (Failure mode and effect analysis)
    - Usually analyzed on the vehicle level
  - Define Safety Goals and Safe States

- Classify the results using Severity, Exposure and Controllability as measures

Part 3
Concept Phase/Product Development

- Functional safety concept defines the behavior of the vehicle in order achieve an intended function

- Technical safety concept defines, what one or more ECUs need to implement in order to achieve the intended behavior of the vehicle



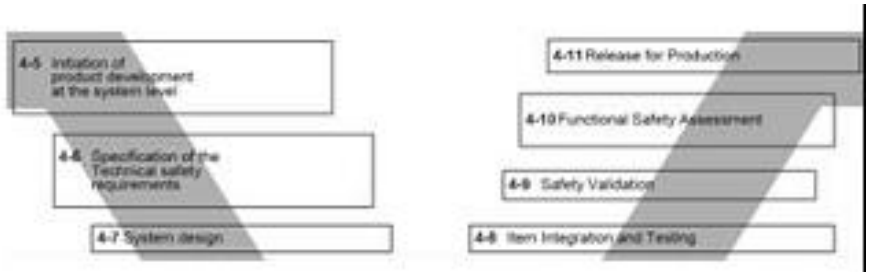
Part 4
Product Development System Level

- Based on the functional safety concept, the technical safety concept is derived
  - The technical safety requirements are mapped to system elements which are hardware or software based

- If a system component fails:
  - means need to be specified which will detect the failure (self control) and
  - a reaction needs to be present which will transition the system into a safe state

- After hardware and software development, there is hardware and software integration, followed by system integration and vehicle integration

- Item integration:
  - Experimental testing (time and cost intensive)
  - Reconfiguration of HW and SW
  - Timing behavior (Analytics)
  - Independence and Interference



Part 4
Product Development System Level

- Finally a validation shows, if the technical safety concept is able to reach the safety goals and if the safety goals and cases from the hazard analysis can be confirmed
  - Development of HW and SW
  - Validation: check if the right HW and SW has been developed
  - Verification: check if the HW and SW has been developed right
  - Check if QM measures have been taken into account
  - Assess whether the mentioned points have been done correctly

- At the end, items are released for mass production
  - Assessment Reports
  - Safety case
  - Existence of all documents required by ISO 26262

Part 4
Product Development System Level

- Item integration and testing
  - Each functional and technical safety requirements shall be tested at least once in the complete integration phase

Methods		ASIL			
		A	B	C	D
1a	Analysis of requirements	++	++	++	++
1b	Analysis of external and internal interfaces	+	++	++	++
1c	Generation and analysis of equivalence classes for hardware software integration	+	+	++	++
1d	Analysis of boundary values	+	+	++	++
1e	Knowledge or experience based error guessing	+	+	++	++
1f	Analysis of functional dependencies	+	+	++	++
1g	Analysis of common limit conditions, sequences, and sources of common cause	+	+	++	++
1h	Analysis of environmental conditions and operational use cases	+	++	++	++
1i	Analysis of field experience	+	++	++	++

”++” The method is highly recommended for this ASIL.

“+“ The method is recommended for this ASIL.

“o“ The method has no recommendation for or against its usage for this ASIL.

Part 5
Product Development Hardware Level

- The scope is to determine and plan the functional safety activities during the individual sub-phases of hardware development, which is included in the safety plan.

- The following metrics are used:
  - Safe Faults
    - do not affect the safety requirements
  - Single point faults metric (SPFM)
    - Is used to show, that the system architecture can detect single point faults.
  - Latent faults metric (LFM)
    - Is used to show, that the architecture is suitable to detect multiple faults (dual-faults).
  - Residual Faults
    - Fault which are not detected by any safety mechanisms and which lead to a violation of the safety requirements

Part 6
Product Development Software Level

- The scope is to plan and initiate the functional safety activities for the following sub-phases of the software development. Specifically, appropriate methods, and relative tools shall be determine to achieve the requirements of the assigned ASIL

- The main safety related software components are used for diagn ostic coverage
  - The self control SW may have as many LOCs as the SW for function

- Key issues in the SW development process are:
  - Model Based Development
  - Software Configuration
  - Freedom from Interference

- Requirements compared by ASIL
  - 244 requirements ASIL A
  - 308 requirements ASIL D

Part 6
Product Development Software Level

- Metrics for SW Unit Testing
- Statement Coverage
  - Call foo(1, 1)
- Branch Coverage
  - Call foo(1, 1) and foo(0, 1)
- Modified Condition/Decision Coverage
  - Call foo(0, 0), foo(0, 1), foo(1, 0), foo(1, 1)

```
int foo (int x, int y)
{
    int z = 0;
    if ((x>0) && (y>0)) {
        z = x;
    }
    return z;
}
```

Method	ASIL A	ASIL B	ASIL C	ASIL D
Statement Coverage C_0	++	++	+	+
Branch Coverage C_1	+	++	++	++
Modified Condition MC/ Decision Coverage DC	+	+	+	++

Part 6
Product Development Software Level
(Metrics for Software Testing)

- Function Coverage
  - Makes sure, that a specific function gets called
- Call Coverage
  - Makes sure that each function gets called

Method	ASIL A	ASIL B	ASIL C	ASIL D
Function Coverage	+	+	++	++
Call Coverage	+	+	++	++

Part 7
Production and Operation

- Covers Production, Operation and Service
- Planning of the Activities and realization of the planned activities
- One important aspect is the Product observation duties which means that data from the field is communicated back to the OEM (Original equipment manufacturer).
  - This data is the basis for the argumentation of proven in use.

Part 8
Supporting Processes

- Interfaces in case of distributed Development
- Specification Management of Safety Requirements
- Configuration Management
- Change Management
- Verification
- Documentation
- Qualification of Software Tools
- Qualification of Software Components
- Qualification of Hardware Components
- Argumentation of the Proven in Use

Detail Study of ISO-26262

ISO 26262 – 2 : 2011
Management of Functionality Safety

Scope

- Applied to the passenger cars with series production, that has features:
  - Electrical or Electronic (E/E) systems
  - Vehicle Mass up to 3 500 kg

- Does not addresses
  - Special purpose vehicles (such as drivers with disabilities)
  - Hazards related to electric shock, fire, smoke, heat, radiation, toxicity, flammability, reactivity, corrosion, release of energy **unless directly caused by malfunctioning behavior of E/E safety-related systems**

Part-2 specifies the Requirements for functional safety management for automotive applications

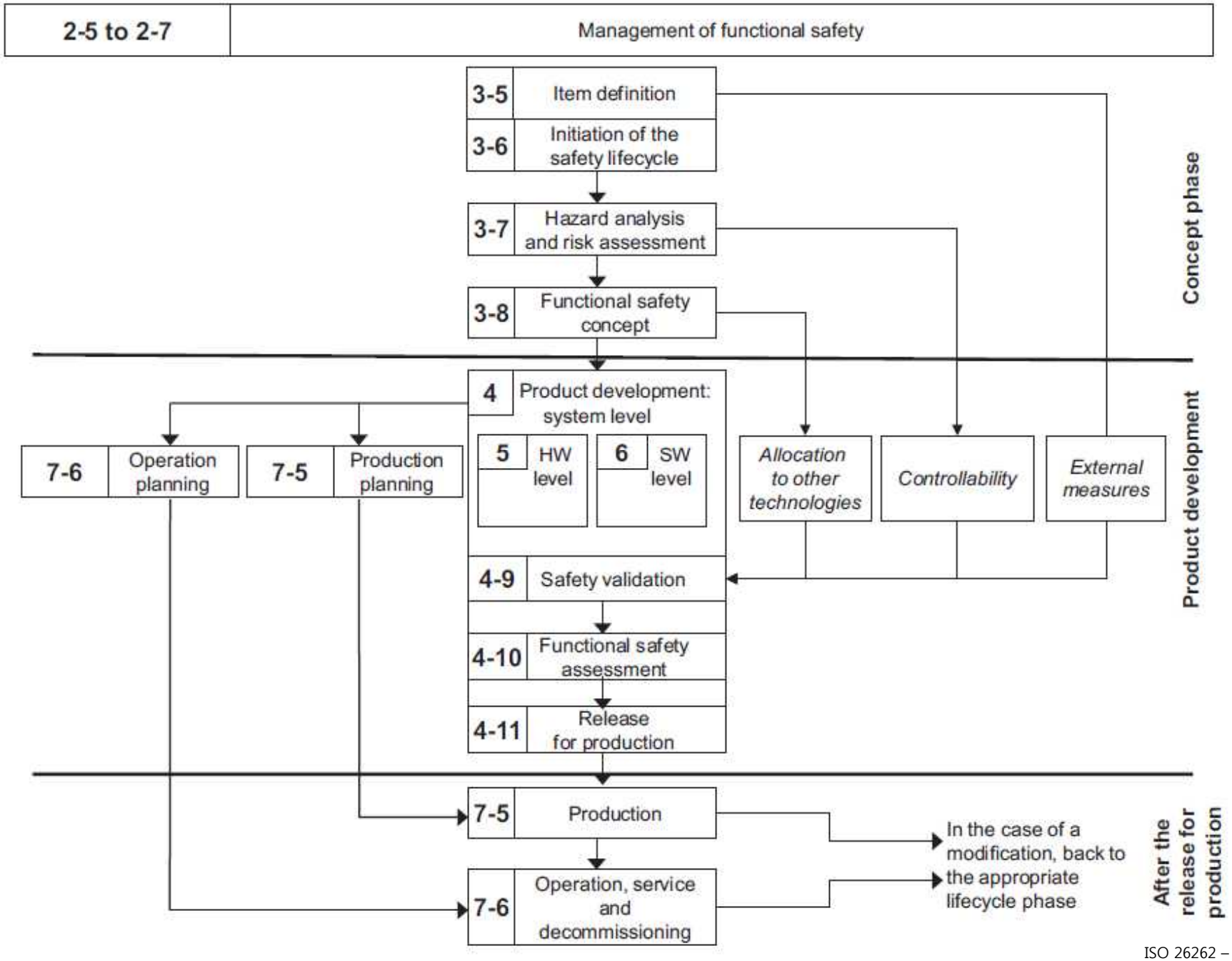
- Project-independent requirements with regard to the organizations involved
  - Overall Safety Management

- Project-specific requirements with regard to the management activities in the safety lifecycle
  - Management during the concept phase
  - Product development
  - After release for production

Normative References

- ISO 26262-1:2011, *Road vehicles — Functional safety — Part 1: Vocabulary*
- ISO 26262-3:2011, *Road vehicles — Functional safety — Part 3: Concept phase*
- ISO 26262-4:2011, *Road vehicles — Functional safety — Part 4: Product development at the system level*
- ISO 26262-5:2011, *Road vehicles — Functional safety — Part 5: Product development at the hardware level*
- ISO 26262-6:2011, *Road vehicles — Functional safety — Part 6: Product development at the software level*
- ISO 26262-7:2011, *Road vehicles — Functional safety — Part 7: Production and operation*
- ISO 26262-8:2011, *Road vehicles — Functional safety — Part 8: Supporting processes*
- ISO 26262-9:2011, *Road vehicles — Functional safety — Part 9: Automotive Safety Integrity Level (ASIL)-oriented and safety-oriented analyses*

Safety Lifecycle



ISO 26262 – 2 : 2011

Key Management Tasks

- Plan
- Coordinate
- Track

- Requirements for the management of functional safety:
  - Overall safety management
  - Safety management during concept phase and product development
  - Safety management after item's release for production

Competence Management

- The organization shall ensure
  - the **persons involved** in the execution of the **safety lifecycle** have a sufficient level of skills, competences and qualifications corresponding to their responsibilities
  - to achieve a sufficient level of skills and competences in development is a training and qualification program:
    - Usual safety practices, concepts and designs
    - ISO 26262 and, if applicable, further safety standards
    - organization-specific rules for functional safety
    - functional safety processes instituted in the organization
  - To evaluate the skills, competences and qualifications to carry out activities to comply with ISO 26262
    - domain knowledge of the item
    - expertise on the environment of the item
    - management experience
- Quality management during the safety lifecycle
  - The organizations involved in the execution of the safety lifecycle shall have an operational quality management system complying with a quality management standard, such as ISO/TS 16949, ISO 9001

6. Safety management during the concept phase and the product development

Objective

- Confirmation Measures should be performed. It include confirmation reviews, functional safety audits and functional safety assessments:
  - the confirmation reviews are intended to check the compliance of selected work products to the corresponding requirements of ISO 26262
  - a functional safety audit evaluates the implementation of the processes required for the functional safety activities
  - a functional safety assessment evaluates the functional safety achieved by the item

Inputs to this clause

- The following information shall be available:
  - organization-specific rules and processes for functional safety in accordance with 5.5.1 (Organization-specific rules and processes for functional safety)
  - evidence of competence in accordance with 5.5.2 (Evidence of competence)
  - evidence of quality management in accordance with 5.5.3 (Evidence of quality management)
  - Optionally: If available, the following information can be considered:
    - project plan (from external source);
    - dependencies on other activities, including other safety activities.

Requirements and recommendations

- **Roles and responsibilities in safety management**
  - A project manager shall be appointed at the initiation of the item development
  - The project manager shall be given the responsibility and the authority, in accordance with 5.4.2.8, to ensure that:
    - the safety activities required to achieve functional safety are performed
    - compliance with ISO 26262 is achieved
  - The project manager shall verify that the organization has provided the required resources for the functional safety activities, in accordance with 5.4.2.6.
  - The project manager shall ensure that the safety manager is appointed, in accordance with 5.4.3.

- **Planning and coordination of the safety activities**
  - The safety manager shall be responsible for the planning and coordination of the functional safety activities in the development phases of the safety lifecycle, in accordance with 5.4.2.8.
  - The safety manager shall be responsible for maintaining the safety plan, and for monitoring the progress of the safety activities against the safety plan
  - The safety plan shall either be
    - referenced in the project plan, or
    - included in the project plan, such that the safety activities are distinguishable.

The Safety Plan Shall Include

- The planning of the activities and procedures for achieving functional safety
- The implementation of project-independent safety activities in accordance with Clause 5 into project-specific safety management
- The definition of the tailored safety activities, in accordance with 6.4.5, if applicable
- The planning of the hazard analysis and risk assessment in accordance with ISO 26262-3:2011, Clause 7
- The planning of the development activities, including the development and implementation of the functional safety concept in accordance with ISO 26262-3:2011
- The planning of the development interface agreement (DIA) in accordance with ISO 26262-8:2011
- The planning of the supporting processes, in accordance with ISO 26262-8
- The planning of the verification activities in accordance with ISO 26262-3, ISO 26262-4, ISO 26262-5, ISO 26262-6 and ISO 26262-8:2011
- The planning of the confirmation reviews, the initiation of the functional safety audit(s) and the initiation of the functional safety assessment in accordance with 6.4.7 to 6.4.9
- The planning of the analysis of dependent failures in accordance with ISO 26262-9:2011
- The provision of the proven in use arguments of the candidates in accordance with ISO 26262-8:2011
- The provision of the confidence in the usage of software tools in accordance with ISO 26262-8:2011

Tailoring of the safety activities

- A safety activity with regard to a specific item development may be tailored (i.e. omitted or performed in a different manner):
  - the tailoring shall be defined in the safety plan and
  - a rationale as to why the tailoring is adequate and sufficient to achieve functional safety shall be available

- If the safety activities are tailored in accordance with 6.4.5.1 because an element is developed separately from an item, then
  - the development of the element developed separately from an item shall be based on a requirement specification that is derived from assumptions on an intended use and context, including its external interfaces
  - the validity of the assumptions on the intended use and context of the element developed separately from an item shall be established

  Example: A microcontroller developed separately from an item.

  NOTE: ISO 26262 as a whole cannot be applied to an element developed separately from an item, because functional safety is not an element property (however, an element of an item can be identified as safety related).

  Functional safety is an item property which can be evaluated by means of a functional safety assessment

Confirmation measures: types, independency and authority

- The confirmation measures specified in Table 1 shall be performed, in accordance with the required level of independency, Table 2, 6.4.3.5 i), 6.4.8 and 6.4.9

- The persons who carry out a confirmation measure shall have access to, and shall be supported by, the persons and organizational entities that carry out safety activities during the item development.

- The persons who carry out a confirmation measure shall have access to the relevant information and tools.

Table 1 — Required confirmation measures, including the required level of independency

Confirmation measures	Degree of independency[a] applies to ASIL				Scope
	A	B	C	D	
Confirmation review of the hazard analysis and risk assessment of the item (see ISO 26262-3:2011, Clauses 5 and 7, and, if applicable, ISO 26262-8:2011, Clause 5) Independence with regard to the developers of the item, project management and the authors of the work product	I3	I3	I3	I3	The scope of this review shall include the correctness of the determined ASILs and quality management (QM) ratings of the identified hazardous events for the item, and a review of the safety goals
Confirmation review of the safety plan (see 6.5.1) Independence with regard to the developers of the item, project management and the authors of the work product	—	I1	I2	I3	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the item integration and testing plan (see ISO 26262-4) Independence with regard to the developers of the item, project management and the authors of the work product	I0	I1	I2	I2	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the validation plan (see ISO 26262-4) Independence with regard to the developers of the item, project management and the authors of the work product	I0	I1	I2	I2	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the safety analyses (see ISO 26262-9:2011, Clause 8) Independence with regard to the developers of the item, project management and the authors of the work products	I1	I1	I2	I3	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the software tool criteria evaluation report and the software tool qualification report[b] (see ISO 26262-8:2011, Clause 11) Independence with regard to the persons performing the qualification of the software tool	—	I0	I1	I1	Applies to the highest ASIL of the requirements that can be violated by the use of the tool

Table 1 (*continued*)

Confirmation measures	Degree of independency[a] applies to ASIL				Scope
	A	B	C	D	
Confirmation review of the proven in use arguments (analysis, data and credit), of the candidates (see ISO 26262-8:2011, Clause 14) Independence with regard to the author of the argument	I0	I1	I2	I3	Applies to the ASIL of the safety goal or requirement related to the considered behaviour, or function, of the candidate
Confirmation review of the completeness of the safety case (see 6.5.3) Independence with regard to the authors of the safety case	I0	I1	I2	I3	Applies to the highest ASIL among the safety goals of the item
Functional safety audit in accordance with 6.4.8 Independence with regard to the developers of the item and project management	—	I0	I2	I3	Applies to the highest ASIL among the safety goals of the item
Functional safety assessment in accordance with 6.4.9 Independence with regard to the developers of the item and project management	—	I0	I2	I3	Applies to the highest ASIL among the safety goals of the item

[a] The notations are defined as follows:

— —: no requirement and no recommendation for or against regarding this confirmation measure;

— I0: the confirmation measure should be performed; however, if the confirmation measure is performed, it shall be performed by a different person;

— I1: the confirmation measure shall be performed, by a different person;

— I2: the confirmation measure shall be performed, by a person from a different team, i.e. not reporting to the same direct superior;

— I3: the confirmation measure shall be performed, by a person from a different department or organization, i.e. independent from the department responsible for the considered work product(s) regarding management, resources and release authority.

[b] A software tool development is outside the item's safety lifecycle whereas the qualification of such a tool is an activity of the safety lifecycle.

Functional safety audit

- A functional safety audit shall be carried out for items, where the highest ASIL of the item's safety goals is ASIL (B), C, or D, in accordance with 6.4.7, 6.4.3.5 i) and 6.4.8.2

- One or more persons shall be appointed to carry out one or more functional safety audits, in accordance with 5.4.3. The appointed persons shall provide a report that contains an evaluation of the implementation of the processes required for functional safety

- Note: If a functional safety audit is performed by a Software Process Improvement and Capability Determination (SPICE) assessor, then this functional safety audit and a SPICE assessment (see ISO/IEC 15504) can be performed simultaneously

Functional safety assessment

- A functional safety assessment shall be carried out for items, where the highest ASIL of the item's safety goals is ASIL (B), C, or D, in accordance with 6.4.7 and 6.4.9.2 to 6.4.9.8.
- A functional safety assessment shall be planned in accordance with 6.4.3.3 and 6.4.3.5 i).

- EXAMPLE: Agenda for a functional safety assessment given in Annex E.

- One or more persons shall be appointed to carry out a functional safety assessment, in accordance with 5.4.3. The appointed persons shall provide a report that contains a judgment of the achieved functional safety
- The scope of a functional safety assessment shall include
  - the work products required by the safety plan
  - the processes required for functional safety
  - reviewing the appropriateness and effectiveness of the implemented safety measures that can be assessed during the item development

- A functional safety assessment shall consider:
  - the planning of the other confirmation measures [see 6.4.3.5 i)];
  - the results from the confirmation reviews and functional safety audit(s)
  - the recommendation(s) resulting from the previous functional safety assessment(s), if applicable (see 6.4.9.7, 6.4.9.8 and ISO 26262-8:2011, 8.4.5.2)

7. Safety management after the item's release for production

- Objective
  - The objective of this clause is to define the responsibilities of the organizations and persons responsible for functional safety **after the item's release for production**.

- Inputs to this clause
  - The following information shall be available
    - evidence of quality management in accordance with 5.5.3 -> 5.4.4 = The organizations involved in the execution of the safety lifecycle shall have an operational quality management system complying with a quality management standard, such as ISO/TS 16949, ISO 9001, or equivalent

- Requirements and recommendations
  - Responsibilities, planning and required processes
  - The organization shall appoint persons with the responsibility and the corresponding authority, in accordance with 5.4.2.8, to maintain the functional safety of the item after its release for production
  - The activities for ensuring the functional safety of the item after its release for production shall be planned, in accordance with ISO 26262-7, and shall be initiated during the product development at the system level in accordance with ISO 26262-4
  - The organization shall institute, execute and maintain processes in order to maintain the functional safety of the item in the lifecycle phases after the release for production.
  - The organization shall institute, execute and maintain a field monitoring process with respect to the item's functional safety
  - If the item changes after its release for production, the release for production in accordance with ISO 26262-4:2011, Clause 11, shall be **reissued**

Requirements and recommendations

- Responsibilities, planning and required processes
- The organization shall appoint persons with the responsibility and the corresponding authority, in accordance with 5.4.2.8, to maintain the functional safety of the item after its release for production
- The activities for ensuring the functional safety of the item after its release for production shall be planned, in accordance with ISO 26262-7, and shall be initiated during the product development at the system level in accordance with ISO 26262-4
- The organization shall institute, execute and maintain processes in order to maintain the functional safety of the item in the lifecycle phases after the release for production.
- The organization shall institute, execute and maintain a field monitoring process with respect to the item's functional safety
- If the item changes after its release for production, the release for production in accordance with ISO 26262-4:2011, Clause 11, shall be **reissued**

Functional safety management: overview

Clause	Objectives	Prerequisites	Work products
5 Overall safety management	The objective of Clause 5 is to define the requirements for the organizations that are responsible for the safety lifecycle, or that perform safety activities in the safety lifecycle. Clause 5 serves as a prerequisite to the activities in the ISO 26262 safety lifecycle.	None	5.5.1 Organization-specific rules and processes for functional safety. 5.5.2 Evidence of competence. 5.5.3 Evidence of quality management.
6 Safety management during the concept phase and the product development	The first objective of Clause 6 is to define the safety management roles and responsibilities, regarding the concept phase and the development phases in the safety lifecycle. The second objective of Clause 6 is to define the requirements for the safety management during the concept phase and the development phases, including the planning and coordination of the safety activities, the progression of the safety lifecycle, the creation of the safety case, and the execution of the confirmation measures.	Organization-specific rules and processes for functional safety (see 5.5.1) Evidence of competence (see 5.5.2) Evidence of quality management (see 5.5.3)	6.5.1 Safety plan. 6.5.2 Project plan (refined). 6.5.3 Safety case. 6.5.4 Functional safety assessment plan. 6.5.5 Confirmation measure reports.
7 Safety management after the item's release for production	The objective of Clause 7 is to define the responsibilities of the organizations and persons responsible for functional safety after the item's release for production. This relates to the general activities for ensuring the required functional safety of the item during the lifecycle subphases after the release for production.	Evidence of quality management (see 5.5.3).	7.5 Evidence of field monitoring.

Examples for Evaluating a Safety Culture

Examples indicative of a poor safety culture	Examples indicative of a good safety culture
Accountability is not traceable	The process assures that accountability for decisions related to functional safety is traceable
Cost and schedule always take precedence over safety and quality	Safety is the highest priority
The reward system favours cost and schedule over safety and quality	The reward system supports and motivates the effective achievement of functional safety The reward system penalizes those who take shortcuts that jeopardize safety or quality
Personnel assessing safety, quality and their governing processes are influenced unduly by those responsible for executing the processes	The process provides adequate checks and balances, e.g. the appropriate degree of independence in the integral processes (safety, quality, verification, validation and configuration management)
Passive attitude towards safety, e.g. — heavy dependence on testing at the end of the product development cycle, — management reacts only when there is a problem in the field	Proactive attitude towards safety, e.g. — safety and quality issues are discovered and resolved from the earliest stage in the product lifecycle
The required resources are not planned or allocated in a timely manner	The required resources are allocated Skilled resources have the competence commensurate with the activity assigned
No systematised continuous improvement processes, learning cycles or other forms of “lessons learned”	Continuous improvement is integral to all processes

ISO 26262 – 2 : 2011

Overview of Verification reviews

Verification review subject	Highest ASIL among the safety goals of the item				Clause in which required or recommended
	A	B	C	D	
Hazard analysis and risk assessment of the item (see ISO 26262-3:2011, Clauses 5 and 7, and, if applicable, ISO 26262-8:2011, Clause 5)	required[a]				ISO 26262-3:2011, Clause 7
Safety goals	required				ISO 26262-3:2011, Clause 7
Functional safety concept	required				ISO 26262-3:2011, Clause 8
Technical safety requirements specification	required				ISO 26262-4:2011, Clause 6
System design	required				ISO 26262-4:2011, Clause 7
Hardware safety requirements	required				ISO 26262-5:2011, Clause 6
Hardware design	required				ISO 26262-5:2011, Clause 7
Results of the applied methods with regard to the evaluation of the hardware architectural metrics	[b]	recommended	required	required	ISO 26262-5:2011, Clause 8
Analysis of the potential safety goal violations due to random hardware failures, considering the applied evaluation method	[b]	recommended	required	required	ISO 26262-5:2011, Clause 9
Software safety requirements and the refined hardware-software interface requirements	required				ISO 26262-6:2011, Clauses 6 and 11
Software architectural design	required				ISO 26262-6:2011, Clause 7
Software unit design and implementation	required				ISO 26262-6:2011, Clause 8
Software component qualification report	required for the qualified software components				ISO 26262-8:2011, Clause 12
Hardware component qualification report	required for the qualified hardware components				ISO 26262-8:2011, Clause 13
Safety analyses	required				ISO 26262-9:2011, Clause 8

[a] The scope of this review also includes hazardous events rated as QM.

[b] No requirement and no recommendation for or against.

ISO 26262 – 2 : 2011

ISO 26262 – 3 : 2011
Concept Phase

Contents

- Item Definition
- Initiation of the safety lifecycle
- Hazard analysis and risk assessment
- Functional safety concept

Item Definition

- Objectives
  - The first objective is:
    - to define and describe the item
    - its dependencies on
    - interaction with the environment and other items
  - The second objective is:
    - to support an adequate understanding of the item
    - so that the activities in subsequent phases can be performed.

- Further Supporting Information
  - Any information that already exists:
    - concerning the item
    - a product idea
    - a project sketch
    - relevant patents
    - the results of pre-trials
    - the documentation from predecessor items
    - relevant information on other independent items.

Item Definition - Requirements and Recommendations

- The functional and non-functional requirements of the item as well as the dependencies between the item and its environment shall be made available
  - the functional concept, describing the purpose and functionality, including the operating modes and states of the item;
  - the operational and environmental constraints;
  - legal requirements (especially laws and regulations), national and international standards;
  - behavior achieved by similar functions, items or elements, if any
  - assumptions on behavior expected from the item
  - potential consequences of behavior short falls including known failure modes and hazards

- The boundary of the item, its interfaces, and the assumptions concerning its interaction with other items and elements, shall be defined considering:
  - the elements of the item
  - the assumptions concerning the effects of the item's behavior on other items or elements, that is the
  - environment of the item;
  - interactions of the item with other items or elements;
  - functionality required by other items, elements and the environment;
  - functionality required from other items, elements and the environment;
  - the allocation and distribution of functions among the involved systems and elements
  - the operating scenarios which impact the functionality of the item.

ISO 26262 – 3 : 2011

Initiation of the safety lifecycle

- **Objectives**
  - make the distinction between a new item development and a modification to an existing item
  - define the safety lifecycle activities (ISO 26262-2:2011, Figure 2) that will be carried out in the case of a modification

- **Inputs to this clause**
  - any existing information, not already covered by the item definition, being useful for conducting the impact analysis (Item definition stands for Requirements and Recommendations).

    EXAMPLE: Product concept, requests for change, implementation planning, proven in use argument.

Initiation of the safety lifecycle

Requirements and recommendations

- Determination of the development category
  - It shall be determined whether the item is either a new development, or if it is a modification of an existing item or its environment:
    - in the case of a new development, the development shall be continued with the hazard analysis and risk assessment in accordance with Clause 7
    - in the case of a modification of the item or its environment the applicable lifecycle sub-phases and activities shall be determined in accordance with 6.4.2

      NOTE: A proven in use argument can be applied to modification

Initiation of the safety lifecycle

Requirements and recommendations

- Impact analysis and possible tailored safety lifecycle, in the case of modification
  - An impact analysis shall be carried out in order to identify and describe the intended modification applied to the item or its environment and to assess the impact of these modifications
  - The impact analysis shall identify and address areas affected by the modifications to the item and modifications between previous and future conditions of use of the item, including:
    - operational situations and operating modes
    - interfaces with the environment
    - installation characteristics such as location within the vehicle, vehicle configurations and variants
    - a range of environmental conditions e.g. temperature, altitude, humidity, vibrations, Electromagnetic
    - Interference (EMI) and fuel types
  - The implication of the modification with regard to functional safety shall be identified and described.
  - The affected work products that need to be updated shall be identified and described.
  - The safety activities shall be tailored in accordance with the applicable lifecycle phases.
  - Tailoring shall be based on the results of the impact analysis.
  - The results of tailoring shall be included in the safety plan in accordance with ISO 26262-2:2011, 6.4.3.
  - The affected work products shall be reworked. NOTE: The affected work products include the validation plan (see ISO 26262-4).
  - In the case of missing work products or work products that do not comply with ISO 26262, the necessary activities to reach ISO 26262 compliance shall be determined.

Hazard analysis and risk assessment

- Objectives
  - Identify and to categorize the hazards that malfunctions in the item can trigger and to formulate the safety goals related to the prevention or mitigation of the hazardous events, in order to avoid unreasonable risk

Hazard analysis and risk assessment

Requirements and recommendations

- Initiation of the hazard analysis and risk assessment
  - The hazard analysis and risk assessment shall be based on the item definition.
  - The item without internal safety mechanisms shall be evaluated during the hazard analysis and risk assessment

- Situation analysis and hazard identification
  - Situation analysis
    - The operational situations and operating modes in which an item's malfunctioning behavior will result in a hazardous event shall be described, both for cases when the vehicle is correctly used and when it is incorrectly used in a foreseeable way
  - Hazard identification
    - The hazards shall be determined systematically by using adequate techniques
    - Hazards shall be defined in terms of the conditions or behavior that can be observed at the vehicle level
    - The hazardous events shall be determined for relevant combinations of operational situations and hazards
    - The consequences of hazardous events shall be identified
  - Classification of hazardous events (Continue on next page)

Hazard analysis and risk assessment

Requirements and recommendations

- Situation analysis and hazard identification (Continue)
  - Classification of hazardous events
    - All hazardous events identified in 7.4.2.3 shall be classified, except those that are outside the scope of ISO 26262.
    - The severity of potential harm shall be estimated based on a defined rationale for each hazardous event. The severity shall be assigned to one of the severity classes S0, S1, S2 or S3 in accordance with Table 1.
    - The severity class S0 may be assigned if the hazard analysis determines that the consequences of a malfunctioning behavior of the item are clearly limited to material damage and do not involve harm to persons. If a hazard is assigned to severity class S0, no ASIL assignment is required.
    - The probability of exposure of each operational situation shall be estimated based on a defined rationale for each hazardous event. The probability of exposure shall be assigned to one of the probability classes, E0, E1, E2, E3 and E4, in accordance with Table 2.
    - The number of vehicles equipped with the item shall not be considered when estimating the probability of exposure

	Class			
	S0	**S1**	**S2**	**S3**
Description	No injuries	Light and moderate injuries	Severe and life-threatening injuries (survival probable)	Life-threatening injuries (survival uncertain), fatal injuries

Hazard analysis and risk assessment

Requirements and recommendations

- Situation analysis and hazard identification (Continue)
  - Classification of hazardous events
    - The probability of exposure of each operational situation shall be estimated based on a defined rationale for each hazardous event. The probability of exposure shall be assigned to one of the probability classes, E0, E1, E2, E3 and E4, in accordance with Table 2.
    - The number of vehicles equipped with the item shall not be considered when estimating the probability of exposure
    - Class E0 may be used for those situations that are suggested during hazard analysis and risk assessment, but which are considered to be extremely unusual, or incredible, and therefore not followed up. A rationale shall be recorded for the exclusion of these situations. If a hazard is assigned to exposure class E0, no ASIL assignment is required

	Class				
	E0	**E1**	**E2**	**E3**	**E4**
Description	Incredible	Very low probability	Low probability	Medium probability	High probability

Hazard analysis and risk assessment

Requirements and recommendations

- Situation analysis and hazard identification (Continue)
  - Classification of hazardous events
    - The controllability of each hazardous event, by the driver or other persons potentially at risk, shall be estimated based on a defined rationale for each hazardous event. The controllability shall be assigned to one of the controllability classes C0, C1, C2 and C3 in accordance with Table 3.
    - Class C0 may be used for hazards addressing the unavailability of the item if they do not affect the safe operation of the vehicle (e.g. some driver assistance systems). Class C0 may also be assigned if dedicated regulations exist that specify the functional performance with respect to a defined hazard, and C0 is argued using the corresponding existing experience concerning sufficient controllability. If a hazard is assigned to the controllability class C0, no ASIL assignment is required.

	Class			
	C0	**C1**	**C2**	**C3**
Description	Controllable in general	Simply controllable	Normally controllable	Difficult to control or uncontrollable

Hazard analysis and risk assessment

Requirements and recommendations

- Situation analysis and hazard identification (Continue)
  - Determination of ASIL and safety goals
    - An ASIL shall be determined for each hazardous event using the parameters "severity", "probability of exposure" and "controllability" in accordance with Table 4.
    - It shall be ensured that the chosen level of detail of the list of operational situations does not lead to an inappropriate lowering of the ASIL of the corresponding safety goals.

Severity class	Probability class	Controllability class		
		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

Hazard analysis and risk assessment

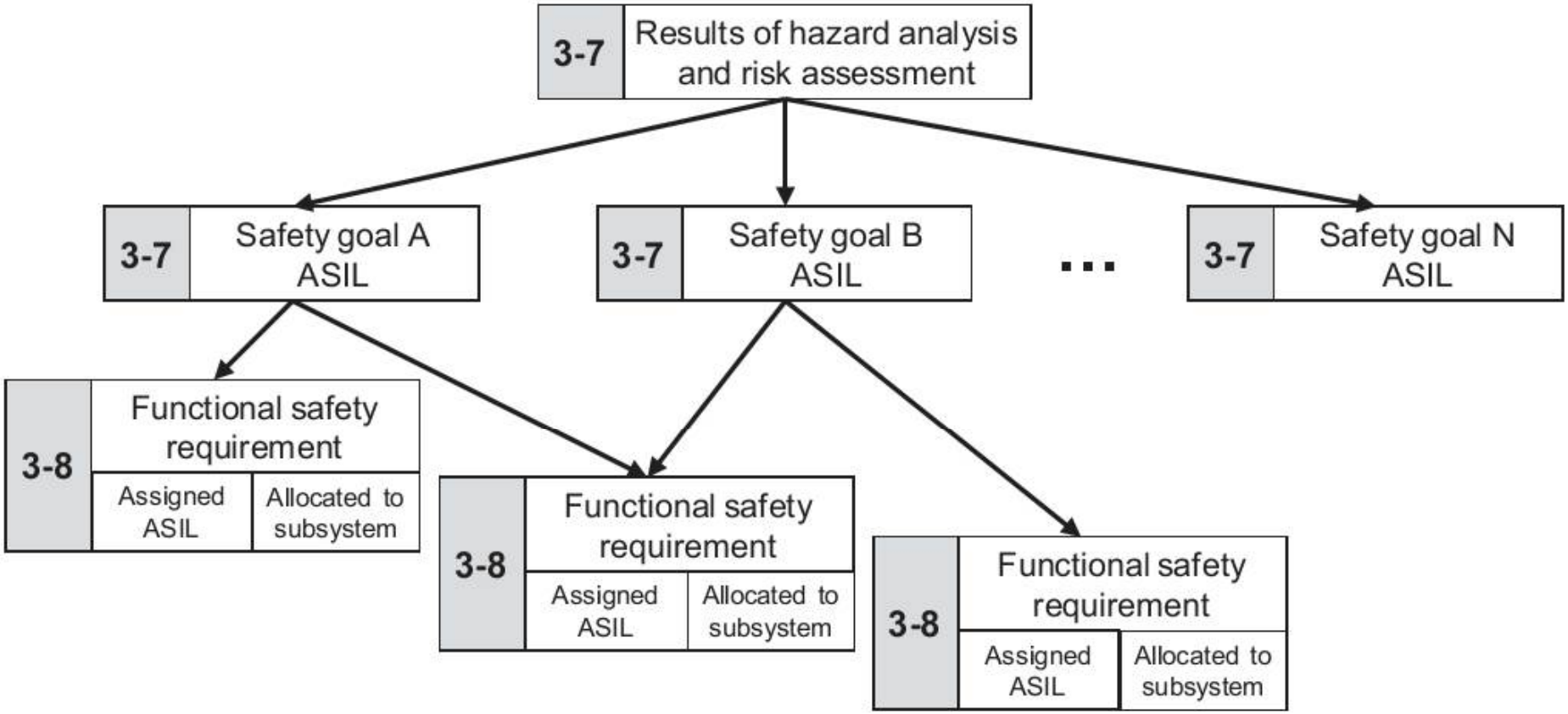
Requirements and recommendations

- Situation analysis and hazard identification (Continue)
  - Verification
    - The hazard analysis, risk assessment and the safety goals shall be verified in accordance with ISO 26262-8:2011, Clause 9, to show their:
      - completeness with regard to situations (7.4.2.1) and hazards (7.4.2.2);
      - compliance with the item definition;
      - consistency with related hazard analyses and risk assessments;
      - completeness of the coverage of the hazardous events; and
      - consistency of the assigned ASILs with the corresponding hazardous events.

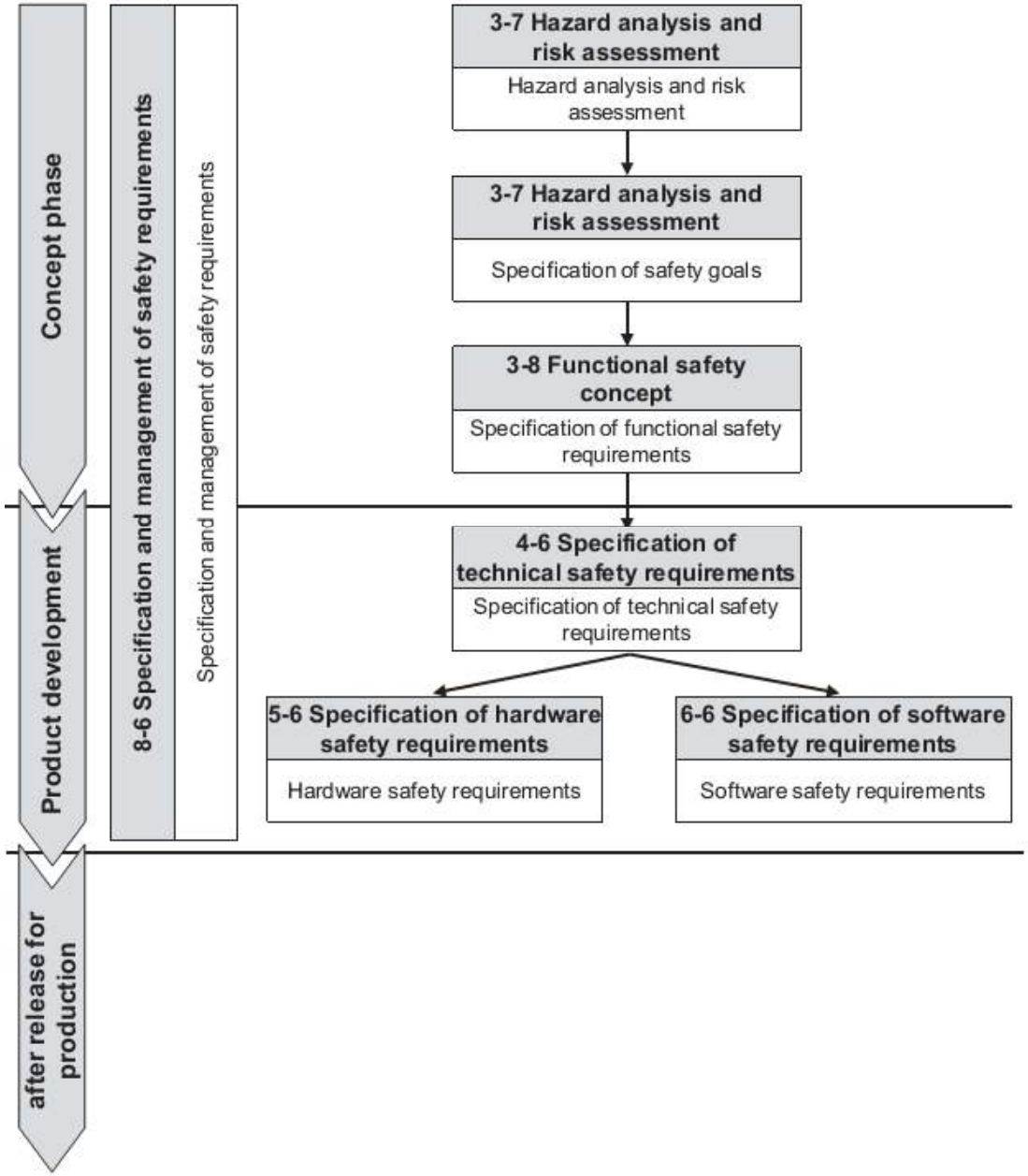
Functional safety concept

- Objectives
  - The objective of the functional safety concept is to derive the functional safety requirements, from the safety goals, and to allocate them to the preliminary architectural elements of the item, or to external measures.
- General
  - It complies with the safety goals
  - contains safety measures
  - safety mechanisms
  - implemented in the item's architectural elements and specified in the functional safety requirements
  - The functional safety concept addresses:
    - fault detection and failure mitigation;
    - transitioning to a safe state;
    - fault tolerance mechanisms, where a fault does not lead directly to the violation of the safety goal(s) and
    - which maintains the item in a safe state (with or without degradation);
    - fault detection and driver warning in order to reduce the risk exposure time to an acceptable interval (e.g. engine malfunction indicator lamp, ABS fault warning lamp)
    - arbitration logic to select the most appropriate control request from multiple requests generated simultaneously by different functions.

Safety goals are determined as a result of the hazard analysis and risk assessment (Hierarchical Approach)



Structure of the Safety Requirements



ISO 26262 – 3 : 2011

Requirements and recommendations

- Derivation of functional safety requirements
  - The functional safety requirements shall be derived from the safety goals and safe states, taking into account the preliminary architectural assumptions
  - At least one functional safety requirement shall be specified for each safety goal
  - Each functional safety requirement shall be specified by considering the following, if applicable:
    - operating modes;
    - fault tolerant time interval;
    - safe states;
    - emergency operation interval, and
    - functional redundancies
  - If a safe state cannot be reached by a transition within an acceptable time interval, an emergency operation shall be specified
  - The warning and degradation concept shall be specified as functional safety requirements

Requirements and recommendations

- Allocation of functional safety requirements
  - The functional safety requirements shall be allocated to the elements of the preliminary architectural assumptions:
  - During the course of allocation, the ASIL and information given in 8.4.2.3 shall be inherited from the associated safety goal or, if ASIL decomposition is applied, from the level above.
  - If several functional safety requirements are allocated to the same architectural element, then the architectural element shall be developed in accordance with the highest ASIL for those safety requirements if independence or freedom from interference cannot be argued in the preliminary architecture.
  - If the item comprises more than one system, then the functional safety requirements for the individual systems and their interfaces shall be specified, considering the preliminary architectural assumptions.
  - These functional safety requirements shall be allocated to the systems.
  - If ASIL decomposition is applied during the allocation of the functional safety requirements, then it shall be applied in accordance with ISO 26262-9:2011

Requirements and recommendations

- Validation
  - The acceptance criteria for safety validation of the item shall be specified based on the functional safety requirements

- Verification of the functional safety concept
  - The functional safety concept shall be verified in accordance with ISO 26262-8:2011
    - its consistency and compliance with the safety goals
    - its ability to mitigate or avoid the hazardous events

Annex B

Hazard analysis and risk assessment

- For this analytical approach, a risk (R) can be described as a function (F), with the frequency of occurrence (f) of a hazardous event, the ability to avoid specific harm or damage through timely reactions of the persons involved, that is the controllability (C) and the potential severity (S) of the resulting harm or damage:

$$R = F(f,C,S)$$

- For this analytical approach, a risk (R) can be described as a function (F), with the frequency of occurrence (f) of a hazardous event, the ability to avoid specific harm or damage through timely reactions of the persons involved, that is the controllability (C) and the potential severity (S) of the resulting harm or damage:

$$f = E \times \lambda$$

- Hazard analysis and risk assessment is concerned with setting requirements for the item such that unreasonable risk is avoided

ISO 26262 – 4 : 2011
Product development at the system level

Main Contents

- Initiation of product development at the system level
- Specification of the technical safety requirements
- System design
- Item integration and testing
- Safety validation
- Functional safety assessment
- Release for production

Initiation of product development at the system level

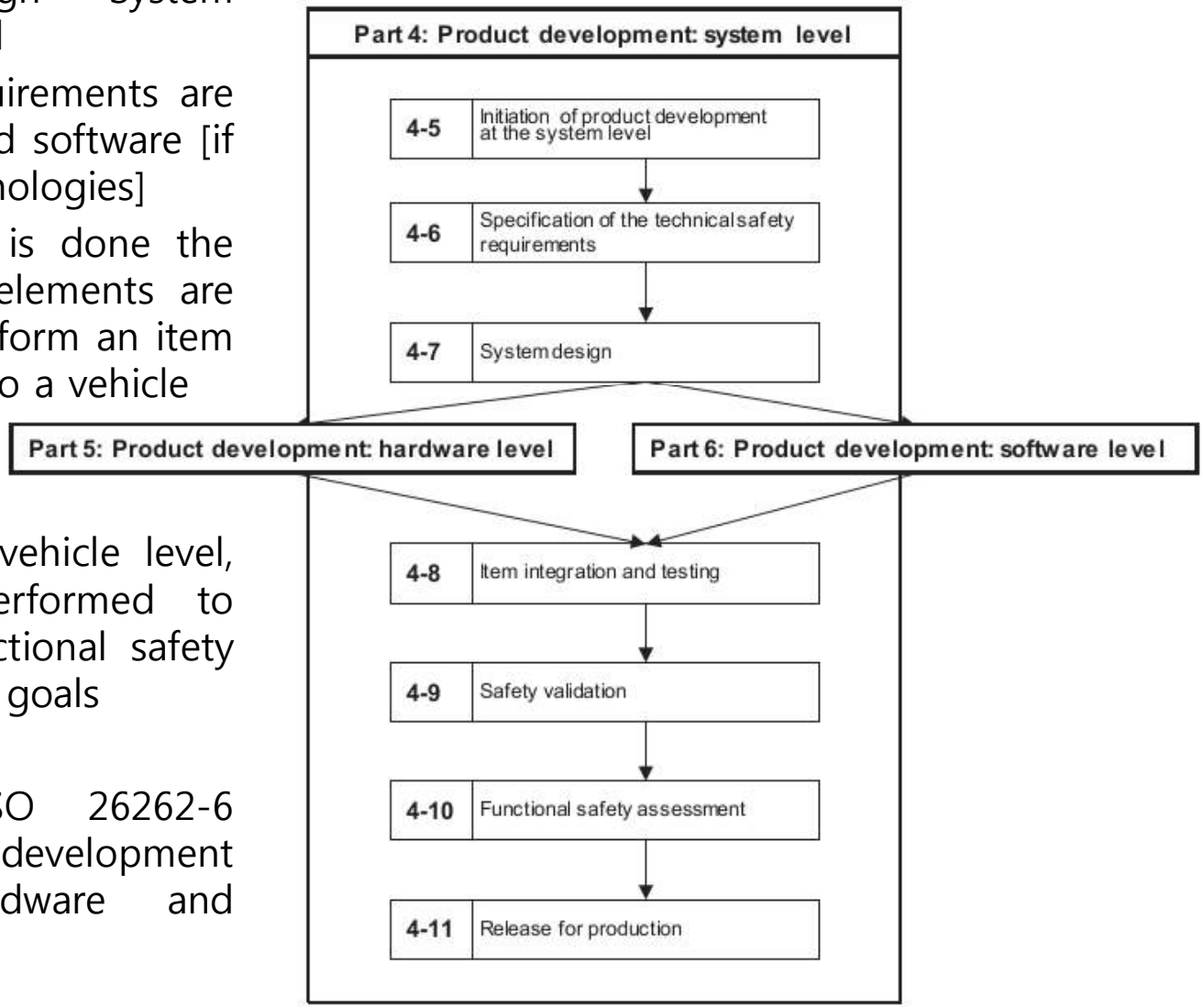
- Objectives
  - The objective of the initiation of the product development at the system level is to **determine and plan the functional safety activities during the individual sub-phases of system development**. This also includes the necessary supporting processes described in ISO 26262-8.
  - Planning of system-level safety activities will be included in the safety plan
- Prerequisites: The following information shall be available:
  - Project plan (refined) in accordance with ISO 26262-2:2011, 6.5.2;
  - Safety plan in accordance with ISO 26262-3:2011, 6.5.2;
  - Functional safety assessment plan in accordance with ISO 26262-2:2011, 6.5.4; and
  - Functional safety concept in accordance with ISO 26262-3:2011, 8.5.1.

Initiation of product development at the system level

- During System Design System Architecture is established
- The technical safety requirements are allocated to hardware and software [if applicable, on other technologies]
- When the development is done the hardware and software elements are integrated and tested to form an item that is then integrated into a vehicle

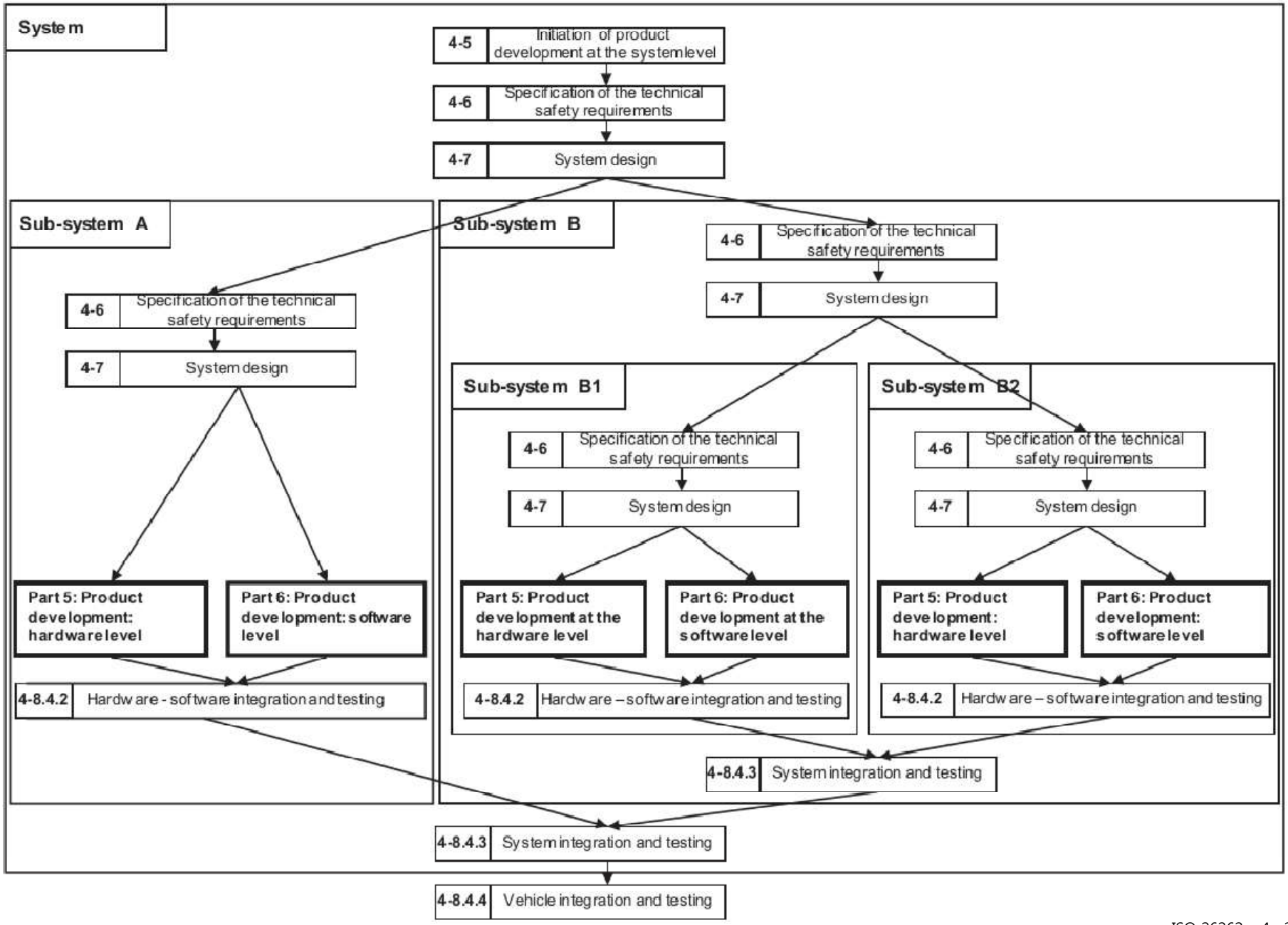
- Once integrated at the vehicle level, safety validation is performed to provide evidence of functional safety with respect to the safety goals

- ISO 26262-5 and ISO 26262-6 describe the development requirements for hardware and software



ISO 26262 – 4 : 2011

Example of a product development at the system level



Requirements and recommendations

- The safety activities for the product development at the system level shall be planned including determination of appropriate methods and measures during design and integration
- The validation activities shall be planned
- The functional safety assessment activities for the product development at the system level shall be planned (see also ISO 26262-2)
- The tailoring of the lifecycle for product development at system level shall be performed in accordance with ISO 26262-2

6 Specification of the technical safety requirements

- Objectives
  - The first objective of this sub-phase is to specify the technical safety requirements. The technical safety requirements specification refines the functional safety concept, considering both the functional concept and the preliminary architectural assumptions (see ISO 26262-3)
  - The second objective is to verify through analysis that the technical safety requirements comply with the functional safety requirements.
- General
  - Within the overall development lifecycle, the technical safety requirements are the technical requirements necessary to implement the functional safety concept, with the intention being to detail the item-level functional safety requirements into the system-level technical safety requirements.

- Requirements and recommendations
  - Specification of the technical safety requirements
  - Safety mechanisms
  - ASIL Decomposition - If ASIL decomposition is applied during the specification of the technical safety requirements it shall be applied in accordance with ISO 26262-9:2011, (Requirements decomposition with respect to ASIL tailoring).
  - Production, operation, maintenance and decommissioning
  - Verification and validation

Specification of the technical safety requirements

- The technical safety requirements shall be specified in accordance with the functional safety concept:
  - the external interfaces, such as communication and user interfaces, if applicable;
  - the constraints, e.g. environmental conditions or functional constraints; and
  - the system configuration requirements.

- If other functions or requirements are implemented by the system or its elements, in addition to those functions for which technical safety requirements are specified in accordance with 6.4.1 (Specification of the technical safety requirements), then these functions or requirements shall be specified or references made to their specification.

- The technical safety requirements shall specify safety-related dependencies between systems or item elements and between the item and other systems

Safety mechanisms

- The technical safety requirements shall specify the response of the system or elements to stimuli that affect the achievement of safety goals. This includes failures and relevant combinations of stimuli in combination with each relevant operating mode and defined system state
  - EXAMPLE: The Adaptive Cruise Control (ACC) ECU disables the ACC functionality if informed by the brake system ECU that the Vehicle Stability Control functionality is unavailable.
- The technical safety requirements shall specify the necessary safety mechanisms:
  - the measures relating to the detection, indication and control of faults in the system itself
  - the measures relating to the detection, indication and control of faults in external devices that interact with the system
    EXAMPLE: External devices include other electronic control units, power supply or communication devices
  - the measures that enable the system to achieve or maintain a safe state
  - the measures to detail and implement the warning and degradation concept
  - the measures which prevent faults from being latent (Avoidance of latent faults)
- For each safety mechanism that enables an item to achieve or maintain a safe state the following shall be specified:
  - the transition to the safe state
  - the fault tolerant time interval
  - the emergency operation interval, if the safe state cannot be reached immediately
    EXAMPLE 1: Switching off can be an emergency operation
  - the measures to maintain the safe state
    EXAMPLE 2: A safety mechanism for a brake-by-wire application, which depends on the power supply, can include the specification of a secondary power supply or storage device

ISO 26262 – 4 : 2011

Avoidance of latent faults

- This requirement applies to ASILs (A), (B), C, and D. if applicable, safety mechanisms shall be specified to prevent faults from being latent

  EXAMPLE: **On-board tests** are safety mechanisms which verify the status of components during the different operation modes such as power-up, power-down, at runtime or in an additional test mode to detect latent faults. Valve, relay or lamp function tests that take place during power up routines are examples of such on-board tests.

- This requirement applies to ASILs (A), (B), C and D, to avoid multiple-point failures, the multiple-point fault detection interval shall be specified for each safety mechanism
  Following Parameters should be considered:
  - the reliability of the hardware component with consideration given to its role in the architecture;
  - the probability of exposure of the corresponding hazardous event(s);
  - the specified quantitative target values for the maximum probability of violation of each safety goal due to
  - hardware random failures
  - the assigned ASIL of the related safety goal.

ISO 26262 – 4 : 2011

Verification and validation

- The technical safety requirements shall be verified in accordance with ISO 26262-8:2011, to provide evidence for their:
  - compliance and consistency with the functional safety concept
  - compliance with the preliminary architectural design assumptions

- The criteria for safety validation of the item shall be refined based on the technical safety requirements

7 System design

- Objectives
  - Develop the system design and the technical safety concept that comply with the functional requirements and the technical safety requirements specification of the item
  - Verify that the system design and the technical safety concept comply with the technical safety requirements specification
- General
  - The development of the system design and the technical safety concept is based on the technical safety requirements specification derived from the functional safety concept. This sub-phase can be applied iteratively, if the system is comprised of subsystems.
  - safety-related and non-safety-related requirements are handled within one development process

System design specification and technical safety concept

- With regard to the implementation of the technical safety requirements the following shall be considered in the system design:
  - the ability to verify the system design
  - the technical capability of the intended hardware and software design with regard to the achievement of functional safety
  - the ability to execute tests during system integration
- Measures for the avoidance of systematic failures

	Methods	ASIL			
		A	B	C	D
1	Deductive analysis[a]	o	+	++	++
2	Inductive analysis[b]	++	++	++	++

[a] Deductive analysis methods include FTA, reliability block diagrams, Ishikawa diagram.

[b] Inductive analysis methods include FMEA, ETA, Markov modelling.

- Identified internal and external causes of systematic failures shall be eliminated or their effects mitigated

ISO 26262 – 4 : 2011

System architectural design constraints

- To reduce systematic failures, well-trusted automotive systems design principles should be applied. These may include the following
  - re-use of well-trusted technical safety concepts;
  - re-use of well-trusted designs for elements, including hardware and software components
  - re-use of well-trusted mechanisms for the detection and control of failures
  - re-use of well-trusted or standardized interfaces.

- To ensure the suitability of well-trusted design principles or elements in the new item, the results of their application shall be analyzed and the underlying assumptions checked before reuse
  - This requirement applies to ASIL D: a decision not to re-use well-trusted design principles should be justified
  - This requirement applies to ASILs (A), (B), C, and D, in order to avoid failures resulting from high complexity, the architectural design shall exhibit all of the following properties
    - modularity;
    - adequate level of granularity
    - simplicity.

ISO 26262 – 4 : 2011

Measures for control of random hardware failures during operation

- Measures for detection and control, or mitigation of random hardware failures shall be specified
  EXAMPLE 1: Such measures can be hardware diagnostic features and their usage by the software to detect random hardware failures
  EXAMPLE 2: A hardware design which directly leads to the safe state in the case of a random hardware failure controls a failure even without detection
- This requirement applies to ASILs (B), C, and D, the target values for single-point fault metric and latent-point fault metric, shall be specified for final evaluation at the item level
- This requirement applies to ASILs (B), C, and D, in accordance with 4.3:one of the alternative procedures of evaluation of violation of the safety goal due to random hardware failures shall be chosen and the target values shall be specified for final evaluation at item level
- This requirement applies to ASILs (B), C, and D, appropriate target values for failure rates and diagnostic coverage should be specified at element level in order to comply with:
  - the target values of the metrics in ISO 26262-5:2011, Clause 8; and
  - the procedures in ISO 26262-5:2011

Allocation to hardware and software

- The technical safety requirements shall be allocated directly or by further refinement to hardware, software or both
- If technical safety requirements are allocated to custom hardware elements that incorporate programmable behavior (such as ASICs, FPGA or other forms of digital hardware) an adequate development process, combining requirements from ISO 26262-5 and ISO 26262-6, should be defined and implemented.

Hardware-software interface specification (HSI)

- The HSI specification shall specify the hardware and software interaction and be consistent with the technical safety concept. The HSI specification shall include the component's hardware devices that are controlled by software and hardware resources that support the execution of software
  The HSI specification shall include the following characteristics:
  - the relevant operating modes of hardware devices and the relevant configuration parameters;
    EXAMPLE 1 Operating modes of hardware devices such as: default, init, test or advanced modes.
    EXAMPLE 2 Configuration parameters such as: gain control, band pass frequency or clock prescaler.
  - the hardware features that ensure the independence between elements and that support software partitioning;
  - shared and exclusive use of hardware resources (such as Memory mapping, allocation of registers, timers, interrupts, I/O ports)
  - the access mechanism to hardware devices (such as Serial, parallel, slave, master/slave)
  - the timing constraints defined for each service involved in the technical safety concept

ISO 26262 – 4 : 2011

Requirements for production, operation, service and decommissioning

- Diagnostic features shall be specified to provide the required data that enables field monitoring for the item or its elements during operation, with consideration being given to the results of safety analyses and the implemented safety mechanisms.

- To maintain functional safety, diagnostic features shall be specified that allow fault identification by workshop staff when servicing is needed

- The requirements for production, operation, service and decommissioning, identified during the system design. These include:
  - the assembly instructions requirements;
  - the safety-related special characteristics;
  - the requirements dedicated to ensure proper identification of systems or elements EXAMPLE 1 Labelling of elements.
  - the verification methods and measures for production;
  - the service requirements including diagnostic data and service notes; and
  - the decommissioning requirements.

ISO 26262 – 4 : 2011

Verification of system design

- The system design shall be verified for compliance and completeness with regard to the technical safety concept using the verification methods listed in Table 3

- Newly identified hazards by the system design not covered in a safety goal shall be introduced and evaluated in the hazard analysis and risk assessment in accordance with ISO 26262-3 and the change management process in ISO 26262-8:2011

Methods		ASIL			
		A	B	C	D
1a	System design inspection[a]	+	++	++	++
1b	System design walkthrough[a]	++	+	o	o
2a	Simulation[b]	+	+	++	++
2b	System prototyping and vehicle tests[b]	+	+	++	++
3	System design analyses[c]	see Table 1			

[a] Methods 1a and 1b serve as a check of complete and correct implementation of the technical safety requirements.

[b] Methods 2a and 2b can be used advantageously as a fault injection technique.

[c] For conducting safety analyses, see ISO 26262-9:2011, Clause 8.

8 Item integration and testing

- Objectives
  - The integration and testing phase comprises three phases and two primary goals as described below:
    - The first phase is the integration of the hardware and software of each element that the item comprises.
    - The second phase is the integration of the elements that comprise an item to form a complete system.
    - The third phase is the integration of the item with other systems within a vehicle and with the vehicle itself.
  - The first objective of the integration process is to test compliance with each safety requirement in accordance with its specification and ASIL classification.
  - The second objective is to verify that the “System design” covering the safety requirements (System design) are correctly implemented by the entire item.

Planning and specification of integration and testing

- To demonstrate that the system design is compliant with the functional and technical safety requirements, integration testing activities shall be performed in accordance with ISO 26262-8:2011
  - the correct implementation of functional safety and technical safety requirements
  - the correct functional performance, accuracy and timing of safety mechanisms
  - the consistent and correct implementation of interfaces
  - the effectiveness of a safety mechanism's diagnostic or failure coverage
  - the level of robustness
- An integration and test strategy shall be defined, which is based on
  - the system design specification
  - the functional safety concept
  - the technical safety concept
  - the item integration
  - the testing plan and provides evidence that the test goals are covered sufficiently
- The test equipment shall be subject to the control of a monitoring quality system
- Each functional and technical safety requirement shall be verified (if applicable by testing) at least once in the complete integration sub-phase.

Hardware-software integration and testing

- The hardware developed in accordance with ISO 26262-5 and the software developed in accordance with ISO 26262-6 shall be integrated to be used as the subject of the test activities in Tables 4 to 8.

Methods		ASIL			
		A	B	C	D
1a	Analysis of requirements	++	++	++	++
1b	Analysis of external and internal interfaces	+	++	++	++
1c	Generation and analysis of equivalence classes for hardware-software integration	+	+	++	++
1d	Analysis of boundary values	+	+	++	++
1e	Error guessing based on knowledge or experience	+	+	++	++
1f	Analysis of functional dependencies	+	+	++	++
1g	Analysis of common limit conditions, sequences, and sources of dependent failures	+	+	++	++
1h	Analysis of environmental conditions and operational use cases	+	++	++	++
1i	Analysis of field experience	+	++	++	++

ISO 26262 – 4 : 2011

Correct implementation of technical safety requirements at the hardware-software level

Methods		ASIL			
		A	B	C	D
1a	Requirements-based test[a]	++	++	++	++
1b	Fault injection test[b]	+	++	++	++
1c	Back-to-back test[c]	+	+	++	++

[a] A requirements-based test denotes a test against functional and non-functional requirements.

[b] A fault injection test uses special means to introduce faults into the test object during runtime. This can be done within the software via a special test interface or specially prepared hardware. The method is often used to improve the test coverage of the safety requirements, because during normal operation safety mechanisms are not invoked.

[c] A back-to-back test compares the responses of the test object with the responses of a simulation model to the same stimuli, to detect differences between the behaviour of the model and its implementation.

ISO 26262 – 4 : 2011

Correct functional performance, accuracy and timing of safety mechanisms at the hardware-software level

	Methods	ASIL			
		A	B	C	D
1a	Back-to-back test[a]	+	+	++	++
1b	Performance test[b]	+	++	++	++

[a] A back-to-back test compares the responses of the test object with the responses of a simulation model to the same stimuli, to detect differences between the behaviour of the model and its implementation.

[b] A performance test can verify the performance (e.g. task scheduling, timing, power output) in the context of the whole test object, and can verify the ability of the intended control software to run with the hardware.

Consistent and correct implementation of external and internal interfaces at the hardware-software level

	Methods	ASIL			
		A	B	C	D
1a	Test of external interfaces[a]	+	++	++	++
1b	Test of internal interfaces[a]	+	++	++	++
1c	Interface consistency check[a]	+	++	++	++

[a] Interface tests of the test object include tests of analogue and digital inputs and outputs, boundary tests and equivalence-class tests to completely test the specified interfaces, compatibility, timings and other specified ratings for the test object. Internal interfaces of an ECU can be tested by static tests for the compatibility of software and hardware as well as dynamic tests of Serial Peripheral Interface- (SPI) or Integrated Circuit- (IC) communications or any other interface between elements of an ECU.

Effectiveness of a safety mechanism's diagnostic coverage at the hardware-software level

	Methods	ASIL			
		A	B	C	D
1a	Fault injection test[a]	+	+	++	++
1b	Error guessing test[b]	+	+	++	++

[a] A fault injection test uses special means to introduce faults into the test object during runtime. This can be done within the software via a special test interface or specially prepared hardware. The method is often used to improve the test coverage of the safety requirements, because during normal operation safety mechanisms are not invoked.

[b] An error guessing test uses expert knowledge and data collected through lessons learned to anticipate errors in the test object. Then a set of tests along with adequate test facilities is designed to check for these errors. Error guessing is an effective method given a tester who has previous experience with similar test objects.

Level of robustness at the hardware-software level

	Methods	ASIL			
		A	B	C	D
1a	Resource usage test[a]	+	+	+	++
1b	Stress test[b]	+	+	+	++

[a] A resources usage test can be done statically (e.g. by checking for code sizes or analyzing the code regarding interrupt usage, in order to verify that worst-case scenarios do not run out of resources), or dynamically by runtime monitoring.

[b] A stress test verifies the test object for correct operation under high operational loads or high demands from the environment. Therefore, tests under high loads on the test object, or with exceptional interface loads, or values (bus loads, electrical shocks, etc.), as well as tests with extreme temperatures, humidity or mechanical shocks, can be applied.

Vehicle Integration and Testing

- The item shall be integrated into the vehicle and the vehicle integration tests shall be completed
- The verification of the interface specification of the item with the in-vehicle communication network and the in-vehicle power supply network shall be performed
- To detect systematic faults during vehicle integration, the test goals, addressed by the application of adequate test methods as given in the corresponding tables
- The correct implementation of the functional safety requirements at the vehicle level shall be demonstrated using feasible test methods (Table below)

Methods		ASIL			
		A	B	C	D
1a	Requirement-based test[a]	++	++	++	++
1b	Fault injection test[b]	++	++	++	++
1c	Long-term test[c]	++	++	++	++
1d	User test under real-life conditions[c]	++	++	++	++

[a] A requirements-based test denotes a test against functional and non-functional requirements.

[b] A fault injection test uses special means to introduce faults into the item. This can be done within the item via a special test interface or specially prepared elements or communication devices. The method is often used to improve the test coverage of the safety requirements, because during normal operation safety mechanisms are not invoked

[c] A long-term test and a user test under real-life conditions are similar to tests derived from field experience but use a larger sample size, normal users as testers, and are not bound to prior specified test scenarios, but performed under real-life conditions during everyday life. These tests can have limitations if necessary to ensure the safety of the testers, e.g. with additional safety measures or disabled actuators.

ISO 26262 – 4 : 2011

Consistent and correct implementation of internal and external interfaces at the vehicle level

	Methods	ASIL A	ASIL B	ASIL C	ASIL D
1a	Test of external interfaces[a]	o	+	++	++
1b	Test of interaction/communication[b]	o	+	++	++

[a] An interface test at the vehicle level tests the interfaces of the vehicle systems for compatibility. This can be done statically by validating value ranges, ratings or geometries as well as dynamically during operation of the whole vehicle.

[b] A communication and interaction test includes tests of the communication between the systems of the vehicle during runtime against functional and non-functional requirements.

Effectiveness of a safety mechanism's failure coverage at the vehicle level

	Methods	ASIL A	ASIL B	ASIL C	ASIL D
1a	Fault injection test[a]	o	+	++	++
1b	Error guessing test[b]	o	+	++	++
1c	Test derived from field experience[c]	o	+	++	++

[a] A fault injection test uses special means to introduce faults into the vehicle. This can be done within the vehicle via a special test interface, specially prepared hardware or communication devices. The method is often used to improve the test coverage of the safety requirements, because during normal operation safety measures are not invoked.

[b] An error guessing test uses expert knowledge and data collected through lessons learned to anticipate errors in the vehicle. Then a set of tests along with adequate test facilities is designed to check for these errors. Error guessing is an effective method given a tester who has previous experience with similar vehicle applications.

[c] A test derived from field experience uses the experience and data gathered from the field. Erroneous vehicle behaviour or newly discovered operational situations are analysed and a set of tests is designed to check the vehicle with respect to the new findings.

Level of robustness at the vehicle level

	Methods	ASIL			
		A	B	C	D
1a	Resource usage test[a]	o	+	++	++
1b	Stress test[b]	o	+	++	++
1c	Test for interference resistance and robustness under certain environmental conditions[c]	o	+	++	++
1d	Long-term test[d]	o	+	++	++

[a] At the item level, resource usage testing is usually performed in dynamic environments (e.g. lab cars or prototypes). Issues to test include item internal resources, power consumption or limited resources of other vehicle systems.

[b] A stress test verifies the correct operation of the vehicle under high operational loads or high demands from the environment. Therefore tests under high loads on the vehicle or with extreme user inputs or requests from other systems as well as tests with extreme temperatures, humidity or mechanical shocks can be applied.

[c] A test for interference resistance and robustness, under certain environmental conditions, is a special case of stress testing. This includes EMC and ESD tests (e.g. see [2], [3]).

[d] A long-term test and a user test under real-life conditions are similar to tests derived from field experience but use a larger sample size, normal users as testers, and are not bound to prior specified test scenarios, but performed under real-life conditions during everyday life.

ISO 26262 – 4 : 2011

9 Safety validation

- Objectives
  - The first objective is to provide evidence of compliance with the safety goals and that the functional safety concepts are appropriate for the functional safety of the item
  - The second objective is to provide evidence that the safety goals are correct, complete and fully achieved at the vehicle level

- The validation plan shall be refined, including:
  - the configuration of the item subjected to validation including its calibration data
  - the specification of validation procedures, test cases, driving maneuvers, and acceptance criteria
  - the equipment and the required environmental conditions

Execution of validation

- If testing is used for validation, then the same requirements as provided for verification testing may be applied
- The safety goals of the item shall be validated at the vehicle level by evaluating the following:
  - the controllability
  - the effectiveness of safety measures for controlling random and systematic failures
  - the effectiveness of the external measures
  - the effectiveness of the elements of other technologies

- Evaluation
  - The results of the validation shall be evaluated

10 Functional safety assessment

- The following information shall be available
  - safety case in accordance with ISO 26262-2:2011
  - safety plan (refined) in accordance with ISO 26262-5:2011 and ISO 26262-6:2011
  - confirmation measure reports in accordance with ISO 26262-2:2011
  - audit report if available in accordance with ISO 26262-2:2011
  - functional safety assessment plan (refined)

- Requirements and recommendation
  - This requirement applies to ASILs (B), C, and D of the safety goal: for each step of the safety lifecycle in ISO 26262-2:2011, the specific topics to be addressed by the functional safety assessment shall be identified
  - This requirement applies to ASILs (B), C, and D of the safety goal: the functional safety assessment shall be conducted in accordance with ISO 26262-2:2011 (Functional safety assessment).

11 Release for production

- Objective
  - The objective of this clause is to specify the release for production criteria at the completion of the item development. The release for production confirms that the item complies with the requirements for functional safety at the vehicle level

- General
  - The release for production confirms that the item is ready for series-production and operation
  - The evidence of compliance with the prerequisites for serial production is provided by:
    - The completion of the verification and validation during the development at the hardware, software, system, item and vehicle level
    - The successful overall assessment of functional safety
  - This release documentation forms a basis for the production of the components, systems or vehicles, and is signed by the person responsible for the release.

Documentation for release for production

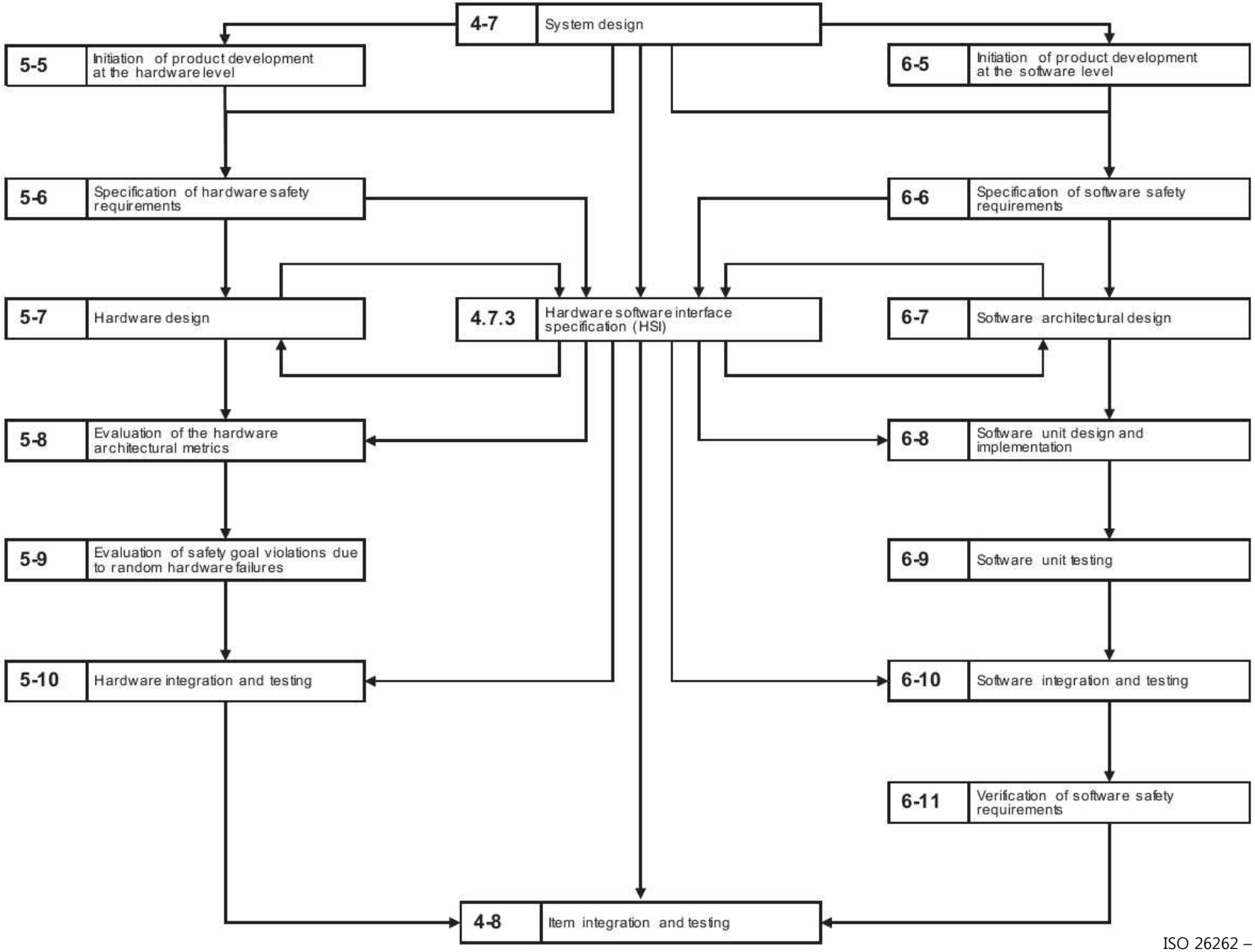
- The documentation of functional safety for release for production shall include the following information:
  - the name and signature of the person responsible for release;
  - the version(s) of the released item;
  - the configuration of the released item;
  - references to associated documents; and
  - the release date.

- At release for production, a baseline for software and a baseline for hardware shall be available, and that shall be documented in accordance with ISO 26262-8:2011

- Identified safety anomalies shall be addressed in accordance with ISO 26262-2:2011

Annex B

Overview on interaction with the hardware-software interfaces



ISO 26262 – 5 : 2011
Product Development at the Hardware Level

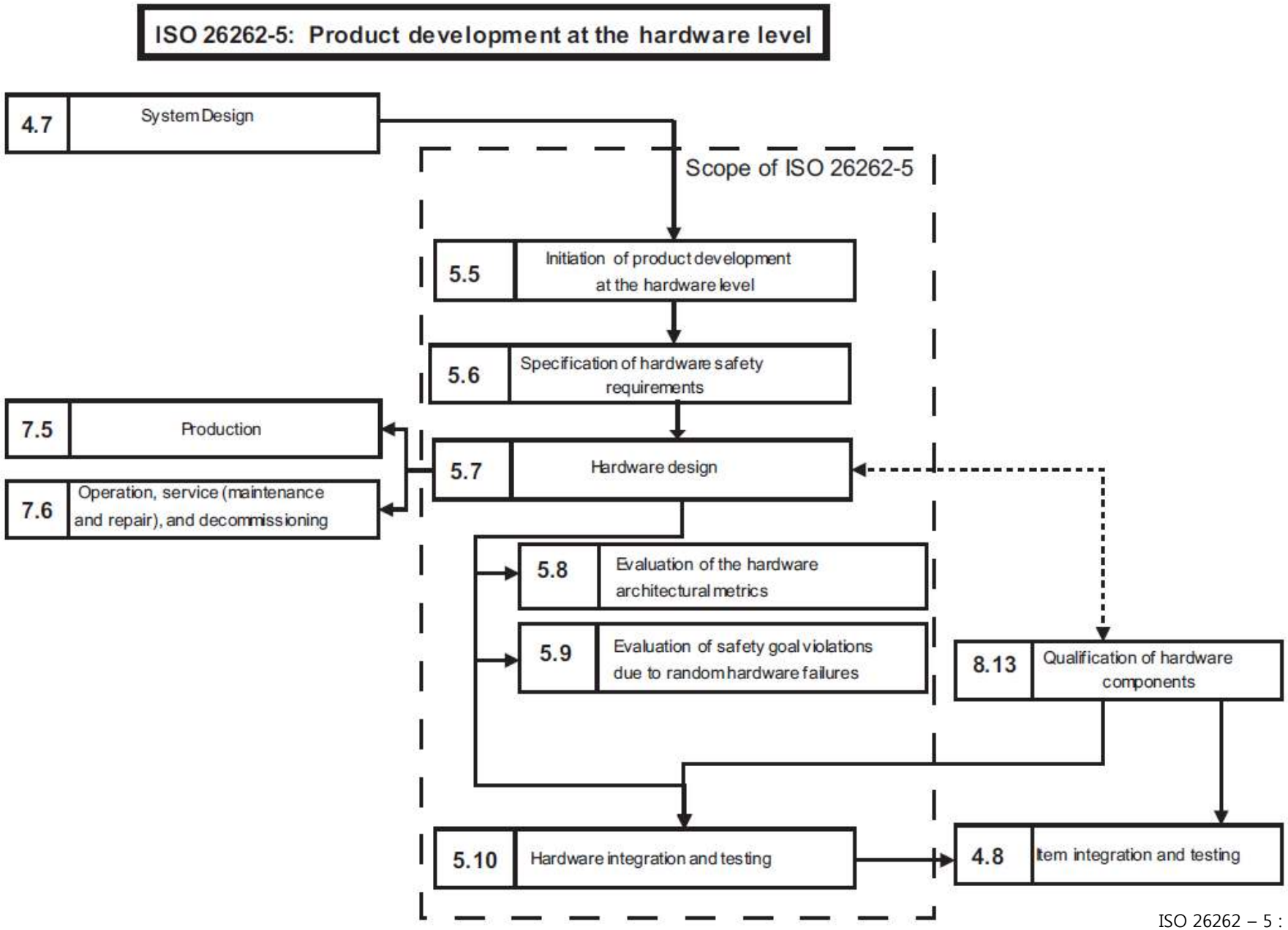
5 Initiation of product development at the hardware level

- Objectives
  - Determine and plan the functional safety activities during the individual sub-phases of hardware development

- The necessary activities and processes for the product development at the hardware level include:
  - Hardware implementation of the technical safety concept
  - The analysis of potential fault and their effects
  - Coordination with software development

- Requirements and Recommendations
  - The hardware development process for the hardware of the item, including methods and tools, shall be consistent across all sub-phases of the hardware development, and consistent with system and software sub-phases
  - The reuse of hardware components, or the use of qualified hardware components or parts, shall be identified and the resulting tailoring of the safety activities shall be described

Reference Phase model for the product development at the hardware level



ISO 26262 – 5 : 2011

6 Specification of Hardware Safety Requirements

- Objectives
  - Specify the hardware safety requirements.
    - Technical safety concept
    - System design specification
  - Verify that the hardware safety requirements are consistent with the technical safety concept and the system design specification

Requirements and Recommendations

- A hardware safety requirements specification for the hardware elements of the item shall be derived from the technical safety requirements allocated to hardware
- The hardware safety requirements specification shall include each hardware requirement that relates to safety, including the following:
  - the hardware safety requirements and relevant attributes of safety mechanisms to control internal failures of the hardware of the element, this includes internal safety mechanisms to cover transient faults when shown to be relevant due, for instance, to the technology used
  - the hardware safety requirements and relevant attributes of safety mechanisms to ensure the element is tolerant to failures external to the element
  - the hardware safety requirements and relevant attributes of safety mechanisms to comply with the safety requirements of other elements
  - the hardware safety requirements and relevant attributes of safety mechanisms to detect and signal internal or external failures
  - the hardware safety requirements not specifying safety mechanisms
- The criteria for design verification of the hardware of the item or element shall be specified, including environmental conditions (temperature, vibration, EMI, etc.), specific operational environment (supply voltage, mission profile, etc.) and component specific requirements:
  - for verification by qualification for hardware components or part of intermediate complexity
  - for verification by testing
- The hardware safety requirements shall comply with the fault tolerant time interval for safety mechanisms
- The hardware safety requirements shall comply with the multiple-point fault detection interval
- The persons responsible for hardware and software development shall be jointly responsible for the verification of the adequacy of the refined HSI specification

ISO 26262 – 5 : 2011

7 Hardware Design

- Hardware design includes hardware architectural design and hardware detailed design:
  - Hardware architectural design represents all hardware components and their interactions with one another
  - Hardware detailed design is at the level of electrical schematics representing the interconnections between hardware parts composing the hardware components

- In order **to develop a single hardware design** both **hardware safety requirements** as well as all **non-safety requirements** have **to be complied** with.

Hardware Architectural Design

- Each hardware component shall inherit the highest ASIL from the hardware safety requirements it implements
- If ASIL decomposition is applied to the hardware safety requirements during hardware architectural design
- If a hardware element is made of sub-elements that have different ASILs assigned, or sub-elements that have no ASIL assigned and safety-related sub-elements, then each of these shall be treated in accordance with the highest ASIL
- The traceability between the hardware safety requirements and their implementation shall be maintained down to the lowest level of hardware components
- In order to avoid failures resulting from high complexity the hardware architectural design shall exhibit the following properties:
  - Modularity
  - Adequate level of granularity
  - Simplicity
- During a hardware architectural design non-functional causes for failures should be considered (temperature, water, dust, cross-talk …)

ISO 26262 – 5 : 2011

Properties of modular hardware design

	Properties	ASIL			
		A	B	C	D
1	Hierarchical design	+	+	+	+
2	Precisely defined interfaces of safety-related hardware components	++	++	++	++
3	Avoidance of unnecessary complexity of interfaces	+	+	+	+
4	Avoidance of unnecessary complexity of hardware components	+	+	+	+
5	Maintainability (service)	+	+	++	++
6	Testability[a]	+	+	++	++
[a] Testability includes testability during development and operation.					

ISO 26262 – 5 : 2011

Hardware detailed design

- In order to avoid common design faults, relevant lessons learned shall be applied in accordance with ISO 26262-2:2011, 5.4.2.7
- The operating conditions of the hardware parts used in the hardware detailed design shall comply with the specification of their environmental and operational limits.
- Robust design principles should be considered

  NOTE: Robust design principles can be shown by use of checklists based on QM methods

- Safety analysis

	Methods	ASIL			
		A	B	C	D
1	Deductive analysis[a]	o	+	++	++
2	Inductive analysis[b]	++	++	++	++
NOTE The level of detail of the analysis is commensurate with the level of detail of the design. Both methods can, in certain cases, be carried out at different levels of detail.					
[a] A typical deductive analysis method is FTA.					
[b] A typical inductive analysis method is FMEA.					

ISO 26262 – 5 : 2011

8 Evaluation of the hardware architectural metrics

- Objective
  - Evaluate the hardware architecture of the item against the requirements for fault handling as represented by the hardware architectural metrics

- Hardware Architectural metrics are defined to achieve the following objectives:
  - be objectively assessable: metrics are verifiable and precise enough to differentiate between different architectures;
  - support evaluation of the final design (the precise calculations are done with the detailed hardware design);
  - make available ASIL dependent pass/fail criteria for the hardware architecture;
  - reveal whether or not the coverage by the safety mechanisms, to prevent risk from single-point or residual faults in the hardware architecture, is sufficient (single-point fault metric);
  - reveal whether or not the coverage by the safety mechanisms, to prevent risk from latent faults in the hardware architecture, is sufficient (latent-fault metric);
  - address single-point faults, residual faults and latent faults;
  - ensure robustness concerning uncertainty of hardware failure rates;
  - be limited to safety-related elements; and
  - support usage on different element levels, e.g. target values can be assigned to suppliers' hardware elements.

9 Evaluation of safety goal violations due to random hardware failures

- Objectives
  - Make available criteria that can be used in a rationale that the residual risk of a safety goal violation, due to random hardware failures of the item, is sufficiently low ("Sufficiently low" means "comparable to residual risks on items already in use")

- Two Methods to evaluate whether residual risk of safety goal violations is sufficiently low:
  - Probabilistic Metric for random Hardware Failures (PMHF), to evaluate the violation of the considered safety goal using quantified FTA and to compare the result of this quantification with a target value
  - Individual Evaluation of each residual and single-point fault, and of each dual-point failure leading to the violation of the considered safety goal

Evaluation of Probabilistic Metric for random Hardware Failures (PMHF)

- Quantitative target values for violation of each safety goal due to random hardware failures as required in ISO 26262-4:2011

Table 6 — Possible source for the derivation of the random hardware failure target values

ASIL	Random hardware failure target values
D	$<10^{-8}\ h^{-1}$
C	$<10^{-7}\ h^{-1}$
B	$<10^{-7}\ h^{-1}$
NOTE The quantitative target values described in this table can be tailored as specified in 4.1 to fit specific uses of the item (e.g. if the item is able to violate the safety goal for durations longer than the typical use of a passenger car).	

- Quantitative target values should be expressed in terms of average probability per hour over the operational lifetime of the item

- A quantitative analysis of the hardware architecture with respect to the single-point, residual and dual-point faults shall provide evidence that target values of requirement have been achieved. Quantitative analysis shall consider:
  - The architecture of the item
  - Estimated failure rate for the failure modes of each hardware part that would cause a single-point fault or residual fault
  - Estimated failure rate for the failure modes of each hardware part that would cause a dual-point fault
  - The diagnostic coverage of safety-related hardware elements by safety mechanisms; and
  - The exposure duration in the case of dual-point faults

ISO 26262 – 5 : 2011

Evaluation of each cause of safety goal violation

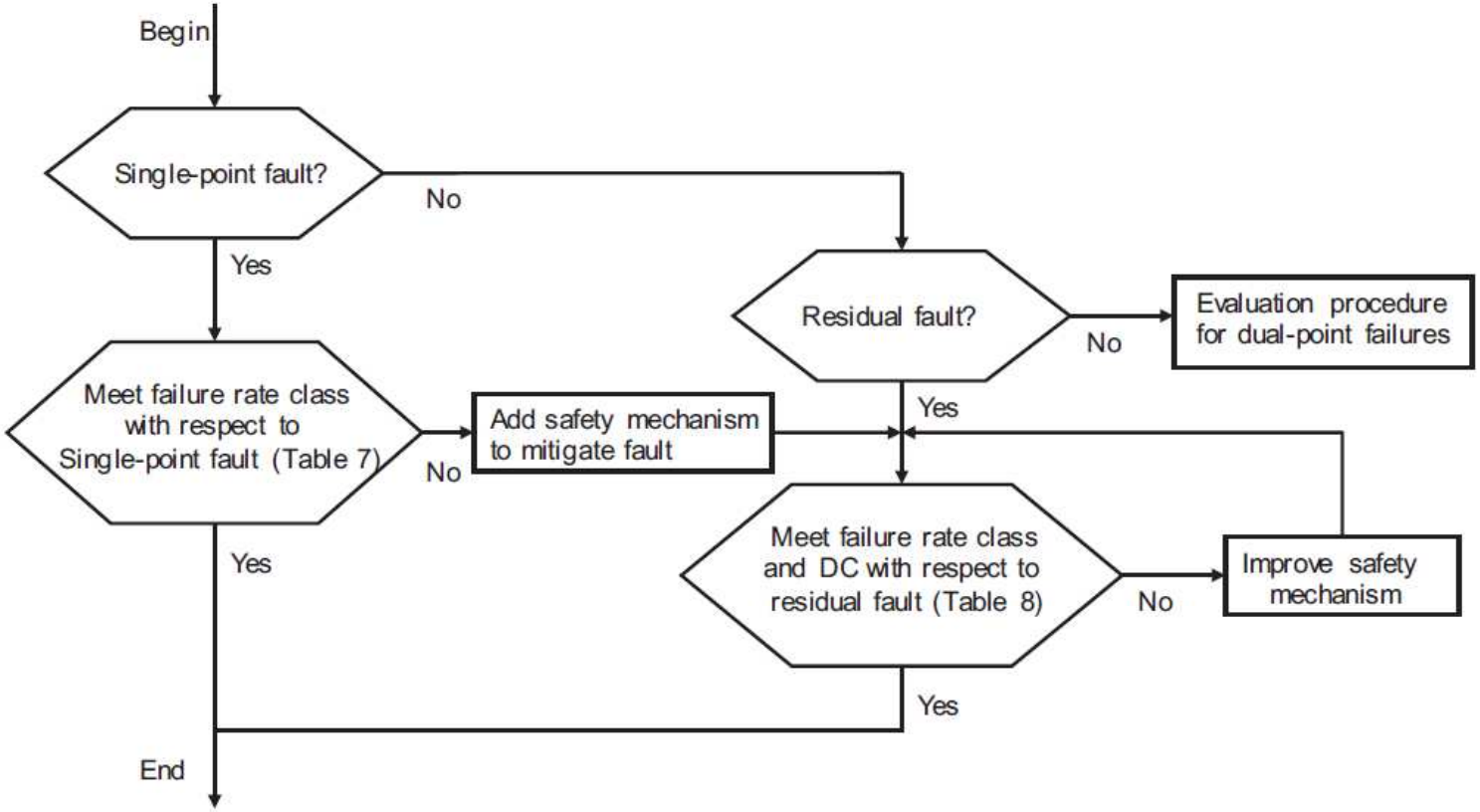


Figure 3 — Evaluation procedure for single-point and residual faults

Table 7 — Targets of failure rate classes of hardware parts regarding single-point faults

ASIL of the safety goal	Failure rate class
D	Failure rate class 1 + dedicated measures[a]
C	Failure rate class 2 + dedicated measures[a] or Failure rate class 1
B	Failure rate class 2 or Failure rate class 1

[a] The note in requirement 9.4.2.4 gives examples of dedicated measures.

Table 8 — Maximum failure rate classes for a given diagnostic coverage of the hardware part – residual faults

ASIL of the safety goal	Diagnostic coverage with respect to residual faults			
	≥99,9 %	≥99 %	≥90 %	<90 %
D	Failure rate class 4	Failure rate class 3	Failure rate class 2	Failure rate class 1 + dedicated measures[a]
C	Failure rate class 5	Failure rate class 4	Failure rate class 3	Failure rate class 2 + dedicated measures[a]
B	Failure rate class 5	Failure rate class 4	Failure rate class 3	Failure rate class 2

[a] The note in requirement 9.4.2.4 gives examples of dedicated measures.

Evaluation of each cause of safety goal violation

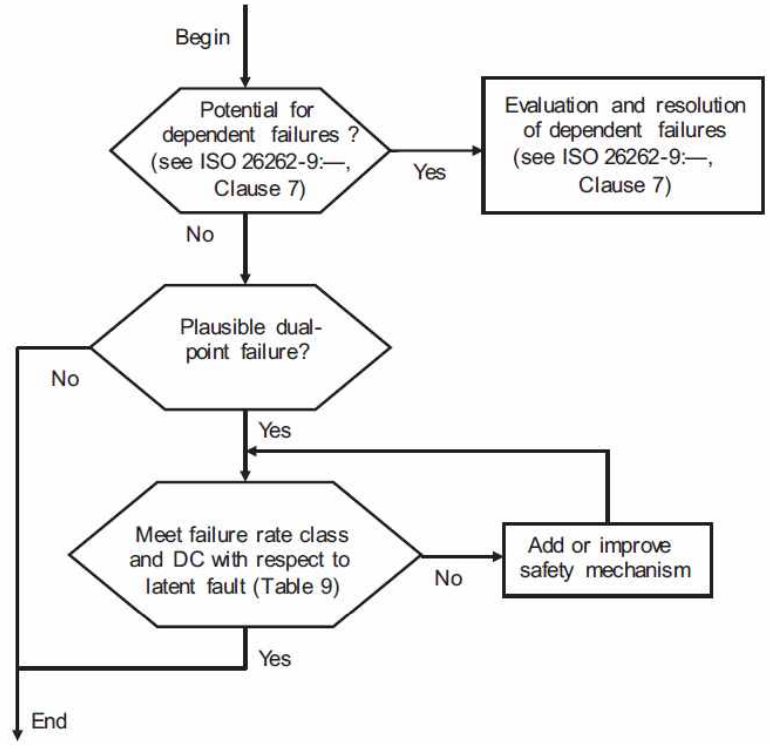


Figure 4 — Evaluation procedure for dual-point failures

- The procedure to be applied for dual-point failures is illustrated by the flowchart in Figure 4. **Each dual-point failure is first evaluated regarding its plausibility**.
  - A dual-point failure is considered **not plausible** if both faults leading to the failure are detected or perceived in a sufficiently short time with sufficient coverage.
  - If the dual-point failure **is plausible**, the faults causing it are then evaluated using criteria combining occurrence of the fault and coverage of the safety mechanisms.
- The evaluation procedures described in Figures 3 and 4 apply to the hardware parts (transistors, etc.) level
- NOTE For complex hardware parts like microcontrollers, it can be appropriate to apply this procedure on a more detailed level like CPU, RAM, ROM, etc

Table 9 — Targets of failure rate class and coverage of hardware part regarding dual-point faults

ASIL of safety goal	Diagnostic coverage with respect to latent faults		
	>= 99 %	>= 90 %	<90 %
D	Failure rate class 4	Failure rate class 3	Failure rate class 2
C	Failure rate class 5	Failure rate class 4	Failure rate class 3

10 Hardware Integration and Testing

- Objectives
  - Ensure by testing, the compliance of the developed hardware with the hardware safety requirements

- Requirements and recommendations
  - Hardware integration and testing activities shall be performed in accordance with ISO 26262-8:2011
  - Hardware integration and testing activities shall be coordinated with the item integration and testing plan given in ISO 26262-4:2011
  - The test equipment shall be subject to the control of a monitoring quality system
  - To enable the appropriate specification of test cases for the selected hardware integration tests, test cases shall be derived using an appropriate combination of methods listed in Table 10
  - The hardware integration and testing activities shall verify the completeness and correctness of the implementation of the safety mechanisms with respect to the hardware safety requirements
  - The hardware integration and testing activities shall verify robustness of hardware against external stresses

Table 10 — Methods for deriving test cases for hardware integration testing

Methods		ASIL			
		A	B	C	D
1a	Analysis of requirements	++	++	++	++
1b	Analysis of internal and external interfaces	+	++	++	++
1c	Generation and analysis of equivalence classes[a]	+	+	++	++
1d	Analysis of boundary values[b]	+	+	++	++
1e	Knowledge or experience based error guessing[c]	++	++	++	++
1f	Analysis of functional dependencies	+	+	++	++
1g	Analysis of common limit conditions, sequences and sources of dependent failures	+	+	++	++
1h	Analysis of environmental conditions and operational use cases	+	++	++	++
1i	Standards if existing[d]	+	+	+	+
1j	Analysis of significant variants[e]	++	++	++	++

[a] In order to derive the necessary test cases efficiently, analysis of similarities can be conducted.

[b] For example, values approaching and crossing the boundaries between specified values, and out of range values.

[c] "Error guessing tests" can be based on data collected through a lessons learned process, or expert judgment, or both. It can be supported by FMEA.

[d] Existing standards include ISO 16750 and ISO 11452.

[e] The analysis of significant variants includes worst-case analysis.

Table 12 — Hardware integration tests to verify robustness and operation under external stresses

Methods		ASIL			
		A	B	C	D
1a	Environmental testing with basic functional verification[a]	++	++	++	++
1b	Expanded functional test[b]	o	+	+	++
1c	Statistical test[c]	o	o	+	++
1d	Worst case test[d]	o	o	o	+
1e	Over limit test[e]	+	+	+	+
1f	Mechanical test[f]	++	++	++	++
1g	Accelerated life test[g]	+	+	++	++
1h	Mechanical Endurance test[h]	++	++	++	++
1i	EMC and ESD test[i]	++	++	++	++
1j	Chemical test [j]	++	++	++	++

[a] During environmental testing with basic functional verification the hardware is put under various environmental conditions during which the hardware requirements are assessed. ISO 16750-4 can be applied.

[b] Expanded functional testing checks the functional behaviour of the item in response to input conditions that are expected to occur only rarely (for instance extreme mission profile values), or that are outside the specification of the hardware (for instance, an incorrect command). In these situations, the observed behaviour of the hardware element is compared with the specified requirements.

[c] Statistical tests aim at testing the hardware element with input data selected in accordance with the expected statistical distribution of the real mission profile. The acceptance criteria are defined so that the statistical distribution of the results confirms the required failure rate.

[d] Worst-case testing aims at testing cases found during worst-case analysis. In such a test, environmental conditions are changed to their highest permissible marginal values defined by the specification. The related responses of the hardware are inspected and compared with the specified requirements.

[e] In over limit testing, the hardware elements are submitted to environmental or functional constraints increasing progressively to values more severe than specified until they stop working or they are destroyed. The purpose of this test is to determine the margin of robustness of the elements under test with respect to the required performance.

[f] Mechanical test applies to mechanical properties such as tensile strength.

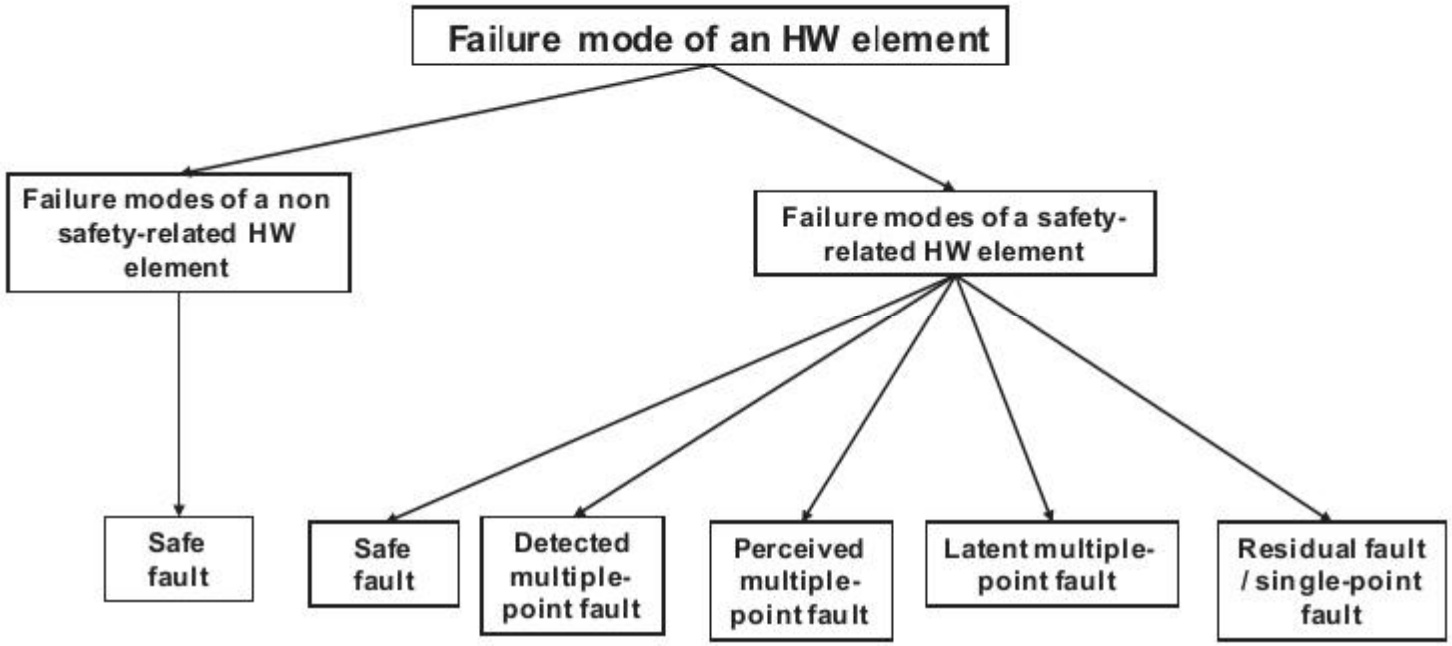
[g] Accelerated life test aims at predicting the behaviour evolution of a product in its normal operational conditions by submitting it to stresses higher than those expected during its operational lifetime. Accelerated testing is based on an analytical model of failure mode acceleration.

[h] The aim of these tests is to study the mean time to failure or the maximum number of cycles that the element can withstand. Test can be performed up to failure or by damage evaluation.

[i] ISO 7637-2, ISO 7637-3, ISO 10605, ISO 11452-2 and ISO 11452-4 can be applied for EMC tests; ISO 16750-2 can be applied for ESD tests.

[j] For chemical tests, ISO 16750-5 can be applied.

Failure mode classifications of a hardware element



ISO 26262 – 5 : 2011

Software Diversified Redundancy (One hardware Channel)

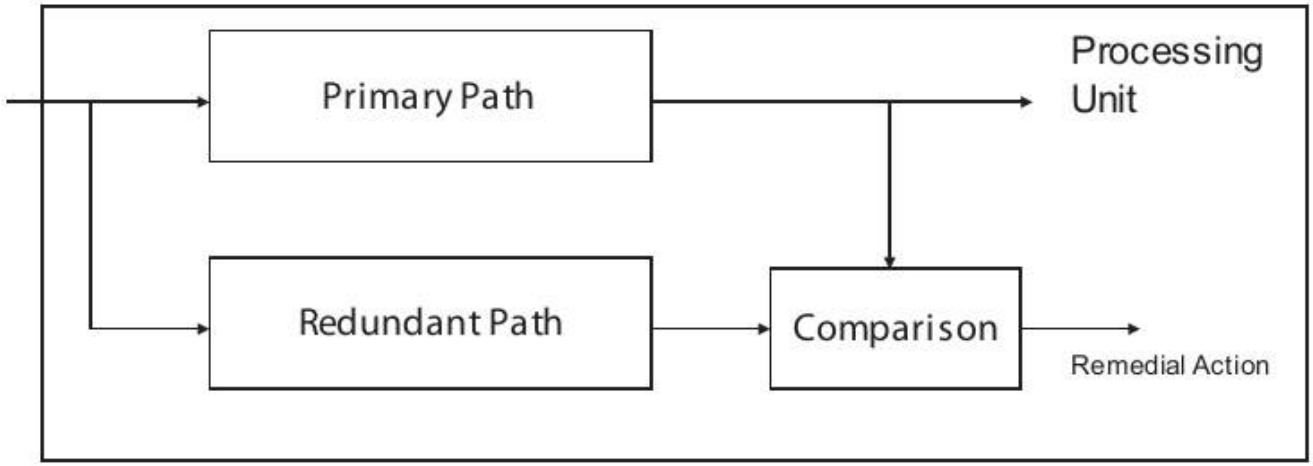


Figure D.2 — Redundant software comparison same processing unit

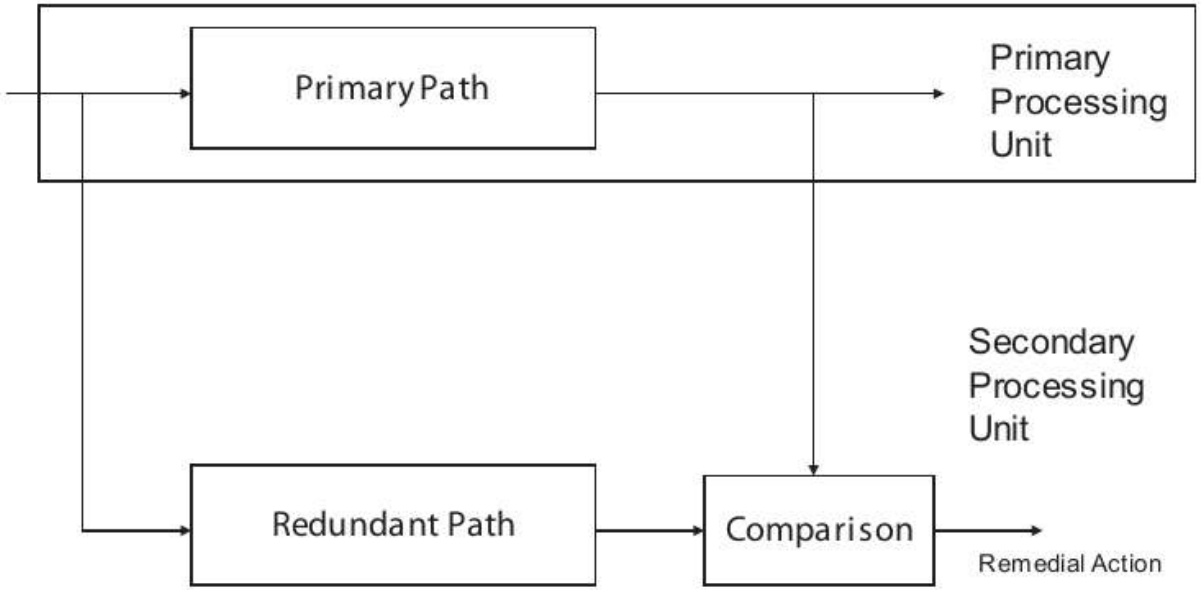


Figure D.3 — Redundant software comparison different processing units

ISO 26262 – 6 : 2011
Product Development at the Software Level

Initiation of Product Development at the software level

- Objective
  - The objective of this sub-phase is to plan and initiate the functional safety activities for the sub-phases of the software development

- Requirements and recommendations
  - The activities and the determination of appropriate methods for the product development at the software level shall be planned
  - The tailoring of the lifecycle for product development at the software level shall be performed in accordance with ISO 26262-2:2011, 6.4.5, and based on the reference phase model
  - If developing configurable software, Annex C shall be applied
  - For each sub-phase of software development, the selection of the following, including guidelines for their application, shall be carried out:
    - Methods
    - Corresponding tools
  - The criteria that shall be considered when selecting a suitable modeling or programming language are:
    - an unambiguous definition
    - the support for embedded real time software and runtime error handling
    - the support for modularity, abstraction and structured construct
  - Note 2: Assembly languages can be used for those parts of the software where the use of high-level programming languages is not appropriate, such as low-level software with interfaces to the hardware, interrupt handlers, or time-critical algorithms

Initiation of Product Development at the software level
Requirements and Recommendations

- To support the correctness of the design and implementation, the design and coding guidelines for the modelling, or programming languages, shall address the topics listed in Table 1

Table 1 — Topics to be covered by modelling and coding guidelines

Topics		ASIL			
		A	B	C	D
1a	Enforcement of low complexity[a]	++	++	++	++
1b	Use of language subsets[b]	++	++	++	++
1c	Enforcement of strong typing[c]	++	++	++	++
1d	Use of defensive implementation techniques	o	+	++	++
1e	Use of established design principles	+	+	+	++
1f	Use of unambiguous graphical representation	+	++	++	++
1g	Use of style guides	+	++	++	++
1h	Use of naming conventions	++	++	++	++

[a] An appropriate compromise of this topic with other methods in this part of ISO 26262 may be required.

[b] The objectives of method 1b are

— Exclusion of ambiguously defined language constructs which may be interpreted differently by different modellers, programmers, code generators or compilers.

— Exclusion of language constructs which from experience easily lead to mistakes, for example assignments in conditions or identical naming of local and global variables.

— Exclusion of language constructs which could result in unhandled run-time errors.

[c] The objective of method 1c is to impose principles of strong typing where these are not inherent in the language.

ISO 26262 – 6 : 2011

6 Specification of software safety requirements

- Objectives
  - The first objective of this sub-phase is to specify the software safety requirements. They are derived from the technical safety concept and the system design specification
  - The second objective is to detail the hardware-software interface requirements initiated in ISO 26262-4:2011
  - The third objective is to verify that the software safety requirements and the hardware-software interface requirements are consistent with the technical safety concept and the system design specification
- General
  - The technical safety requirements are refined and allocated to hardware and software during the system design phase given in ISO 26262-4:2011
  - The specification of the software safety requirements considers constraints of the hardware and the impact of these constraints on the software

Requirements and Recommendations

- The software safety requirements shall address each software-based function whose failure could lead to a violation of a technical safety requirement allocated to software

- EXAMPLE. Functions whose failure could lead to a violation of a safety requirement can be:
  - functions that enable the system to achieve or maintain a safe state
  - functions related to the detection, indication and handling of faults of safety-related hardware elements
  - functions related to the detection, notification and mitigation of faults in the software itself
  - functions related to on-board and off-board tests
  - functions that allow modifications of the software during production and service
  - functions related to performance or time-critical operations

- The specification of the software safety requirements shall be derived from the technical safety concept and the system design in accordance with ISO 26262-4:2011,and shall consider:
  - the specification and management of safety requirements in accordance with ISO 26262-8:2011
  - the specified system and hardware configurations
  - the hardware-software interface specification
  - the relevant requirements of the hardware design specification
  - the timing constraints
  - the external interfaces
  - each operating mode of the vehicle, the system, or the hardware, having an impact on the software

ISO 26262 – 6 : 2011

Requirements and Recommendations

- If ASIL decomposition is applied to the software safety requirements, ISO 26262-9:2011, shall be complied with
- The hardware-software interface specification initiated in ISO 26262-4:2011, Clause 7, shall be detailed down to a level allowing the correct control and usage of hardware, and shall describe each safety-related dependency between hardware and software
- The verification of the software safety requirements and of the refined specification of the hardware software interface shall be planned in accordance with ISO 26262-8:2011
- The refined hardware-software interface specification shall be verified jointly by the persons responsible for the system, hardware and software development
- The software safety requirements and the refined hardware-software interface requirements shall be verified in accordance with ISO 26262-8:2011:
  - compliance and consistency with the technical safety requirements
  - compliance with the system design
  - consistency with the hardware-software interface

ISO 26262 – 6 : 2011

7 Software Architecture Design

- Objectives
  - The first objective of this sub-phase is to develop a software architectural design that realizes the software safety requirements
  - The second objective of this sub-phase is to verify the software architectural design

- General
  - **software architectural design represents** all software **components and their interactions** in a **hierarchical structure.**
  - **Static aspects**, such as **interfaces** and **data paths** between all software components, as well as **dynamic aspects**, such as **process sequences** and **timing behaviors** are described

    NOTE: The software architectural design is not necessarily limited to one microcontroller or ECU, and is related to the technical safety concept and system design. The software architecture for each microcontroller is also addressed by this chapter.

Requirements and Recommendations

- To ensure that the software architectural design captures the information necessary to allow the subsequent development activities to be performed correctly and effectively, the software architectural design shall be described with appropriate levels of abstraction by using the notations for software architectural design listed in Table 2

Table 2 — Notations for software architectural design

Methods		ASIL			
		A	B	C	D
1a	Informal notations	++	++	+	+
1b	Semi-formal notations	+	++	++	++
1c	Formal notations	+	+	+	+

- During the development of the software architectural design the following shall be considered:
  - the verifiability of the software architectural design
  - the suitability for configurable software
  - the feasibility for the design and implementation of the software units
  - the testability of the software architecture during software integration testing
  - the maintainability of the software architectural design

Requirements and Recommendations

- In order to avoid failures resulting from high complexity, the software architectural design shall exhibit the following properties by use of the principles listed in Table 3
  - modularity;
  - encapsulation
  - simplicity.

Table 3 — Principles for software architectural design

Methods		ASIL			
		A	B	C	D
1a	Hierarchical structure of software components	++	++	++	++
1b	Restricted size of software components[a]	++	++	++	++
1c	Restricted size of interfaces[a]	+	+	+	+
1d	High cohesion within each software component[b]	+	++	++	++
1e	Restricted coupling between software components[a, b, c]	+	++	++	++
1f	Appropriate scheduling properties	++	++	++	++
1g	Restricted use of interrupts[a, d]	+	+	+	++

[a] In methods 1b, 1c, 1e and 1g "restricted" means to minimize in balance with other design considerations.

[b] Methods 1d and 1e can, for example, be achieved by separation of concerns which refers to the ability to identify, encapsulate, and manipulate those parts of software that are relevant to a particular concept, goal, task, or purpose.

[c] Method 1e addresses the limitation of the external coupling of software components.

[d] Any interrupts used have to be priority-based.

Requirements and Recommendations

- Every safety-related software component shall be categorized as one of the following:
  - newly developed;
  - reused with modifications; or
  - reused without modifications.
- Safety-related software components that are newly developed or reused with modifications shall be developed in accordance with ISO 26262
- Safety analysis shall be carried out at the software architectural level in accordance with ISO 26262-9:2011, Clause 8, in order to:
  - identify or confirm the safety-related parts of the software
  - support the specification and verify the efficiency of the safety mechanisms

Table 5 — Mechanisms for error handling at the software architectural level

Methods		ASIL			
		A	B	C	D
1a	Static recovery mechanism[a]	+	+	+	+
1b	Graceful degradation[b]	+	+	++	++
1c	Independent parallel redundancy[c]	o	o	+	++
1d	Correcting codes for data	+	+	+	+

[a] Static recovery mechanisms can include the use of recovery blocks, backward recovery, forward recovery and recovery through repetition.

[b] Graceful degradation at the software level refers to prioritizing functions to minimize the adverse effects of potential failures on functional safety.

[c] Independent parallel redundancy can be realized as dissimilar software in each parallel path.

Table 6 — Methods for the verification of the software architectural design

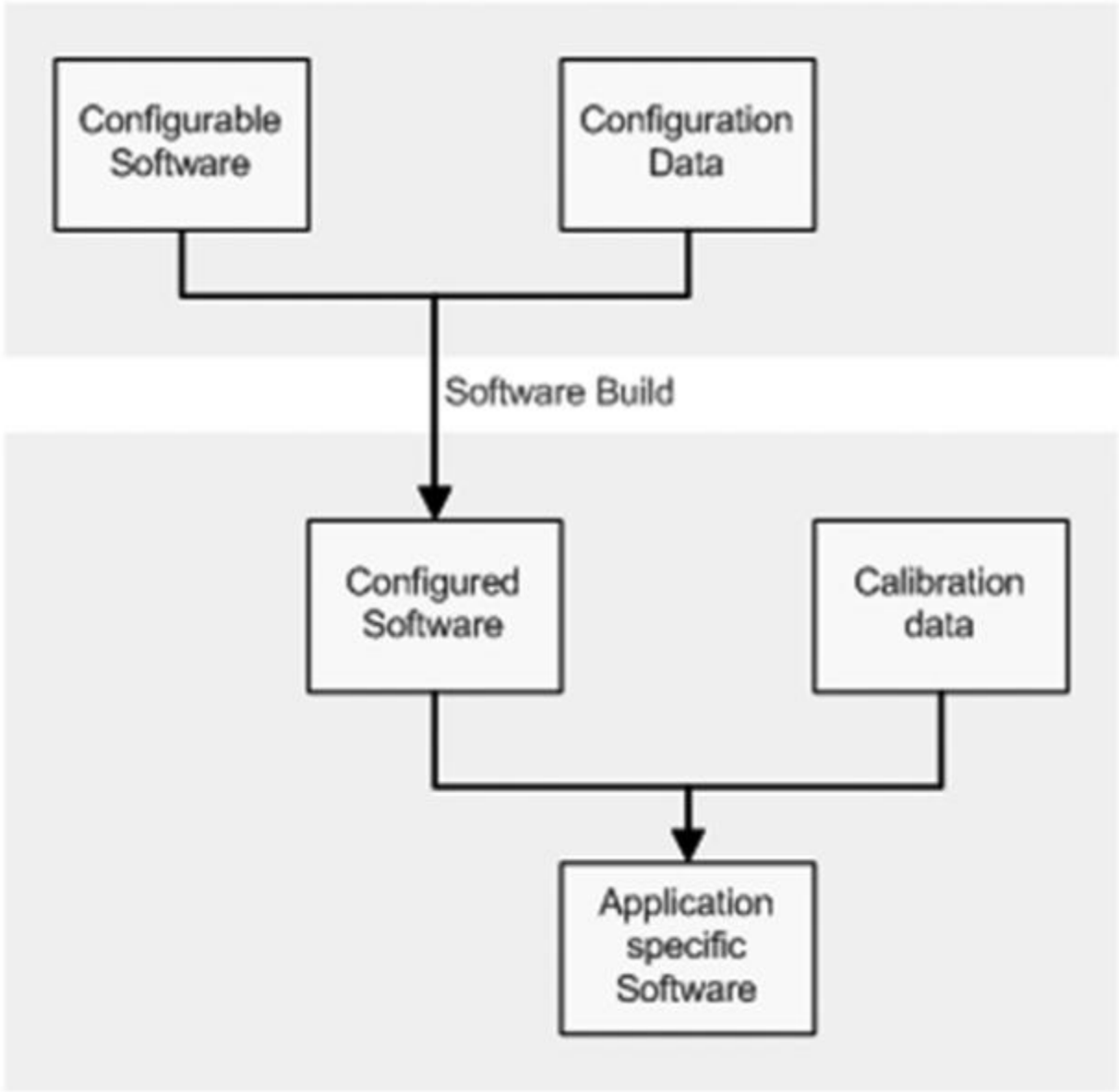
Methods		ASIL			
		A	B	C	D
1a	Walk-through of the design[a]	++	+	o	o
1b	Inspection of the design[a]	+	++	++	++
1c	Simulation of dynamic parts of the design[b]	+	+	+	++
1d	Prototype generation	o	o	+	++
1e	Formal verification	o	o	+	+
1f	Control flow analysis[c]	+	+	++	++
1g	Data flow analysis[c]	+	+	++	++

[a] In the case of model-based development these methods can be applied to the model.

[b] Method 1c requires the usage of executable models for the dynamic parts of the software architecture.

[c] Control and data flow analysis may be limited to safety-related components and their interfaces.

Creating Application Specific Software



ISO 26262 – 6 : 2011

Software Unit Design

Table 7 — Notations for software unit design

Methods		ASIL			
		A	B	C	D
1a	Natural language	++	++	++	++
1b	Informal notations	++	++	+	+
1c	Semi-formal notations	+	++	++	++
1d	Formal notations	+	+	+	+

Table 8 — Design principles for software unit design and implementation

Methods		ASIL			
		A	B	C	D
1a	One entry and one exit point in subprograms and functions[a]	++	++	++	++
1b	No dynamic objects or variables, or else online test during their creation[a,b]	+	++	++	++
1c	Initialization of variables	++	++	++	++
1d	No multiple use of variable names[a]	+	++	++	++
1e	Avoid global variables or else justify their usage[a]	+	+	++	++
1f	Limited use of pointers[a]	o	+	+	++
1g	No implicit type conversions[a,b]	+	++	++	++
1h	No hidden data flow or control flow[c]	+	++	++	++
1i	No unconditional jumps[a,b,c]	++	++	++	++
1j	No recursions	+	+	++	++

[a] Methods 1a, 1b, 1d, 1e, 1f, 1g and 1i may not be applicable for graphical modelling notations used in model-based development.

[b] Methods 1g and 1i are not applicable in assembler programming.

[c] Methods 1h and 1i reduce the potential for modelling data flow and control flow through jumps or global variables.

ISO 26262 – 7: 2011
Production and Operation

5 Production

- Objectives
  - develop and maintain a production process for safety-related elements or items that are intended to be installed in road vehicles
  - achieve functional safety during the production process by the relevant manufacturer or the person or organization responsible for the process

- General
  - The Compliance with safety-related special characteristics of items and elements during their production. Examples of such safety-related special characteristics are specific process parameters (e.g. temperature range or fastening torque), material characteristics, production tolerance, or configuration.

5 Production

(Requirements and Recommendations)

- Production Planning
  - The production process shall be planned by evaluating the item and by considering the following:
    - the requirements for production
      EXAMPLE: Assembly instructions (e.g. the calibration and setup of a sensor); safety-related special characteristics (e.g. the tolerance for the selection of elements).
    - the conditions for storage, transport and handling of hardware elements
      EXAMPLE: Allowed storage time for the element
    - the approved configurations defined in the release for production documentation;
    - the lessons learned on the capability from previously released production plans;
    - The suitability of the production process, means of production, tools and test equipment concerning the safety-related special characteristics
    - the competences of the personnel
  - The production plan shall describe the production steps, sequence and methods required to achieve the functional safety of the item, system or element. It shall include:
    - the production process flow and instructions
    - the production tools and means
    - the implementation of the traceability measures
      EXAMPLE: Labeling for the element
    - if applicable, the implementation of dedicated measures applying to hardware parts and specified during hardware development in accordance with ISO 26262-5:2011

ISO 26262 – 7: 2011

5 Production

(Requirements and Recommendations)

- Production Planning
  - A procedure shall be defined to ensure that the correct embedded software and the associated calibration data are loaded into the ECUs as part of the production process
    - EXAMPLE 1 The use of a checksum, so that the checksum of the loaded executable and configuration data is compared to the correct checksum for this particular model and vehicle configuration
    - EXAMPLE 2 Read back of the part number from the software loaded into the ECUs and comparison with the target part number for that specific vehicle from the bill of materials; as well as read back and comparison of the loaded calibration data with the calibration data for that specific vehicle from the bill of materials
  - The sequence and methods of the control steps shall be described in the production control plan, together with the necessary test equipment, tools and test criteria
  - Reasonably foreseeable process failures and their effects on functional safety shall be identified and the appropriate measures implemented to address the relevant process failures
  - The system, hardware or software development level safety requirements on the producibility of the item, system or element arising during production planning shall be specified and directed to the persons responsible for the development (see ISO 26262-4, ISO 26262-5 and ISO 26262-6)

5 Production

(Requirements and Recommendations)

- Pre-production series production
  - The pre-production process and its control measures should correspond to the target production process
  - Differences between pre-production process and target production process shall be analyzed in order to identify which part of the production process can be assessed at the pre-production stage and for which part of the target production process an assessment will be required

5 Production

(Requirements and Recommendations)

- Production
  - The production process and its control measures shall be implemented and maintained as planned
  - Process failures occurring during production (including deviation of safety-related special characteristics from their authorised range) and their potential effects on functional safety shall be analysed, the appropriate measures shall be taken and their ability to maintain functional safety shall be verified.
  - The capability of the following shall be assessed and maintained with regard to functional safety:
    - production process
    - means of production
    - tools and test equipment

6 Operation, Service and Decommissioning

- Objectives
  - specify the customer information, maintenance and repair instructions, as well as disassembly instructions regarding the item, system or element, in order to maintain the functional safety over the lifecycle of the vehicle
- General
  - provides requirements for developing repair instructions and user information, including the user manual and the planning, execution and monitoring of the maintenance work, taking into account the safety-related special characteristics of the item

6 Operation, Service and Decommissioning
(Requirements and Recommendations)

- **Planning of operation, service (maintenance and repair), and decommissioning**
  - The operation, repair and maintenance processes shall be planned by evaluating the item and by considering the following:
    - the requirements for maintenance and repair
    - the requirements for the information that shall be made available to the user to ensure the safe operation of the vehicle
    - the warning and degradation concept
    - the measures for field data collection and analysis
    - the conditions for storage, transport and handling of the hardware elements
  - The maintenance plan shall describe the sequence and methods of the maintenance steps or activities, the maintenance intervals, and the necessary means of maintenance and tools
  - The maintenance plan and repair instructions shall describe the following:
    - the work steps, procedures, diagnostic routines and methods;
    - the maintenance tools and means
    - the sequence and methods of the control steps and control criteria used to verify the safety-related special characteristics
    - the relevant item, systems or elements configurations, including the traceability measures
    - the allowed deactivation of the item, systems or elements and necessary changes in the vehicle
    - the driver information for the allowed deactivations and changes
    - the provision of replacement parts

6 Operation, Service and Decommissioning
(Requirements and Recommendations)

- User information, including the user's manual, shall provide relevant usage instructions and warnings concerning the proper usage of the item, as well as the following information if applicable
  - a description of the relevant functions, (i.e. the intended usage, the status information or user interaction) and their operating modes;
  - a description of the customer actions required to ensure controllability in the case of a failure indicated by the warning and degradation concept;
  - a description of the maintenance activities expected from the customer in the case of a failure indicated by the warning and degradation concept;
  - the warnings regarding known hazards resulting from interactions with third party products
  - the warnings regarding safety-related innovative functions of the item that could lead to driver's misunderstanding or misuse
- The decommissioning instructions shall describe the activities and measures to be applied before disassembly, and required to prevent the violation of a safety goal during disassembling, handling or decommissioning of the vehicle, the item or its elements.
- System, hardware or software level safety requirements arising during the planning of operation, service (maintenance and repair), and decommissioning, shall be specified and directed to the persons responsible for the development (see ISO 26262-4, ISO 26262-5 and ISO 26262-6)

6 Operation, Service and Decommissioning
(Requirements and Recommendations)

- Operation, Service (maintenance and repair) and Decommissioning
  - The field monitoring process for functional safety incidents that relate to the item shall be implemented as planned in accordance with ISO 26262-2:2011
    - provide the field data that shall be analyzed to detect the presence of any functional safety issues and, if found, trigger actions that address those issues
    - provide the evidence required by the proven in use argument if it is intended to use this argument in accordance with ISO 26262-8:2011
  - The maintenance, repair and decommissioning of the item, its systems or its elements should be conducted and documented in accordance with the maintenance plan and the maintenance and repair instructions
  - The supply of parts and their storage and transport shall be implemented as planned in accordance with 6.4.1.3
  - If changes to the item for subsequent production are initiated by operation, field monitoring, maintenance, repair or decommissioning, a change management process in accordance with ISO 26262-8:2011

ISO 26262 – 8 : 2011
Supporting Process

Contents

- Interfaces within distributed developments
- Specification and management of safety requirements
- Configuration Management
- Change Management
- Verification
- Documentation
- Confidence in the use of software tools
- Qualification of software components
- Qualification of hardware components
- Proven in use argument

5 Interfaces within distributed developments

- Objectives
  - to describe the procedures and to allocate associated responsibilities within distributed developments for items and elements
- General
  - The customer (e.g. vehicle manufacturer) and the suppliers for item developments jointly comply with the requirements specified in ISO 26262
  - Responsibilities are agreed between the customer and the suppliers
  - Subcontractor relationships are permitted
  - comparable procedures are to be agreed for co-operation with the supplier on distributed item developments, or item developments where the supplier has the full responsibility for safety

5 Interfaces within distributed developments
(Requirements and Recommendations)

- Application of requirements
  - These requirements applies to each item and elements developed according to ISO 26262
  - Requirements on the customer-supplier relationship (interfaces and interactions) shall apply to each level of the customer-supplier relationship
- Supplier selection criteria
  - The supplier selection criteria shall include an evaluation of the supplier's capability to develop and produce items and elements of comparable complexity and ASIL according to ISO 26262
  - NOTE Supplier selection criteria includes:
    - evidence of the supplier's quality management system
    - the supplier's past performance and quality
    - the confirmation of the supplier's capability concerning functional safety as part of the supplier's tender
    - results of previous safety assessments according to ISO 26262-2:2011
    - recommendations from the development, production, quality and logistics departments of the vehicle manufacturer as far as they impact functional safety.

5 Interfaces within distributed developments
(Requirements and Recommendations)

- Initiation and planning of distributed development
  - The customer and the supplier shall specify a DIA including the following:
    - the appointment of the customer's and the supplier's safety managers,
    - the joint tailoring of the safety lifecycle in accordance with ISO 26262-2:2011
    - the activities and processes to be performed by the customer and the activities and processes to be performed by the supplier,
    - the information and the work products to be exchanged
    - the parties or persons responsible for the activities
    - the supporting processes and tools, including interfaces, to assure compatibility between customer and supplier
  - If the supplier conducts the hazard analysis and risk assessment, then the hazard analysis and risk assessment shall be provided to the customer for verification.

5 Interfaces within distributed developments
(Requirements and Recommendations)

- Execution of distributed development

  - The supplier shall report to the customer each issue which increases the risk of not conforming to the project plan, the safety plan, integration and testing plan in accordance with ISO 26262-4 or the software verification plan in accordance with ISO 26262-6, or other provisions of the DIA

  - The supplier shall report to the customer each anomaly which occurs during the development activities in their area of responsibility or in that of their subcontractors
  - The supplier shall determine whether each safety requirement can be complied with. If not, the safety concept shall be re-examined and, if necessary, modified to yield safety requirements that will be met
  - Each change potentially affecting the safety of the item or the planned activities to demonstrate compliance with ISO 26262 shall be communicated to the other party to support the impact analysis in accordance with Clause 8
  - Both parties should consider previous experience gained in similar developments in accordance with ISO 26262-2:2011, 5.4.2.7, when deriving safety requirements for the current development
  - This requirement applies to ASIL D in accordance with 4.3. The customer shall be allowed to perform additional functional safety audits at the supplier's premises at any appropriate time

5 Interfaces within distributed developments
(Requirements and Recommendations)

- After release for production
  - The supplier shall provide evidence to the customer that the process capability is being met and maintained in accordance with ISO 26262-2:2011 and ISO 26262-7:2011
  - A supply agreement between the customer and the supplier shall address the responsibilities for functional safety in accordance with ISO 26262-2:2011
  - Each party that becomes aware of a safety-related event shall report this in a timely manner and according to the supply agreement. If a safety-related event occurs, an analysis of that event shall be performed. This analysis should include similar items and related parties which are potentially affected by a similar event.
  - The supply agreement shall state the access to, and exchange of, production monitoring records between the parties for the safety-related special characteristics.

6 Specification and Management of safety requirements

- Objectives
  - ensure the correct specification of safety requirements with respect to their attributes and characteristics
  - ensure consistent management of safety requirements throughout the entire safety lifecycle
- General
  - Safety requirements constitute all requirements aimed at achieving and ensuring the required ASILs
  - During the safety lifecycle, safety requirements are specified and detailed in a hierarchical structure

6 Specification and Management of safety requirements

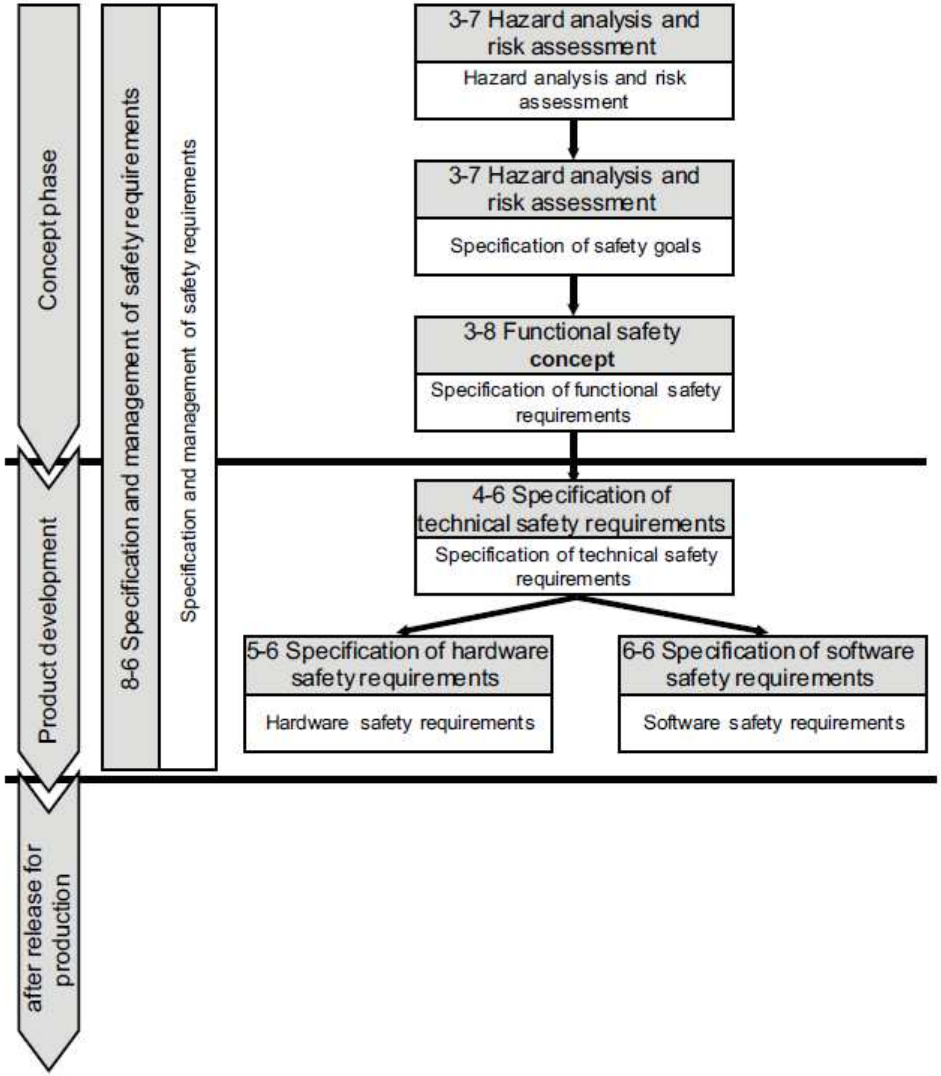


Figure-2 Structure of Safety Requirements

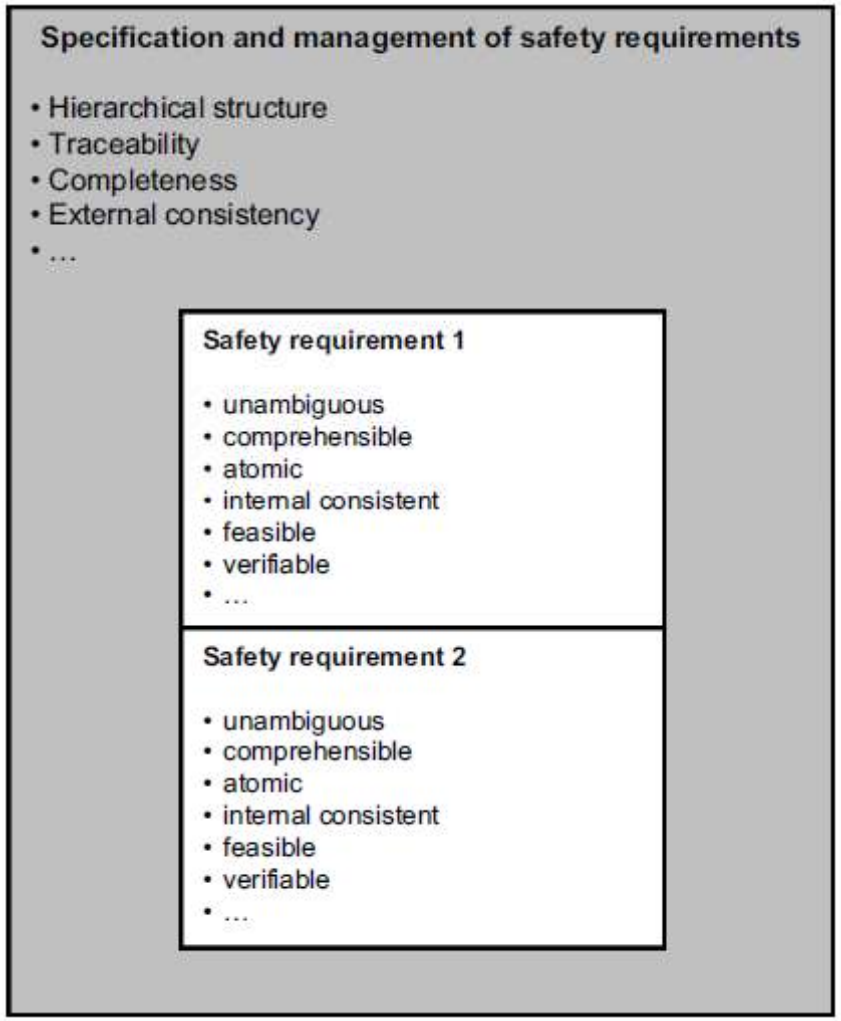


Figure-3. Relationship between management of safety requirements and particular safety requirements

6 Specification and Management of safety requirements (Requirements and Recommendations)

- Specification of safety requirements
  - To achieve the characteristics of safety requirements listed in 6.4.2.4, safety requirements shall be specified by an appropriate combination of:
    - Natural language
    - Methods listed in Table 1

Table 1 — Specifying safety requirements

Methods		ASIL			
		A	B	C	D
1a	Informal notations for requirements specification	++	++	+	+
1b	Semi-formal notations for requirements specification	+	+	++	++
1c	Formal notations for requirements specification	+	+	+	+

- Attributes and characteristics of safety requirements
  - Safety requirements shall be unambiguously identifiable as safety requirements
  - Safety requirements shall inherit the ASIL from the safety requirements from which they are derived, except if ASIL decomposition is applied in accordance with ISO 26262-9
  - Safety requirements shall be allocated to an item or an element
  - Safety requirements shall have the following characteristics:
    - unambiguous and comprehensible
    - Atomic
    - Internally consistent
    - Feasible
    - Verifiable

ISO 26262 – 8 : 2011

6 Specification and Management of safety requirements (Requirements and Recommendations)

- Management of safety requirements
  - The set of safety requirements shall have the following properties:
    - hierarchical structure,
    - Organizational structure according to an appropriate grouping scheme
    - Completeness
    - External consistency
    - No duplication of information within any level of the hierarchical structure
    - Maintainability
  - Safety requirements shall be traceable with a reference being made to:
    - each source of a safety requirement at the upper hierarchical level,
    - each derived safety requirement at a lower hierarchical level, or to its realization in the design, and
    - the specification of verification in accordance with 9.4.2
  - An appropriate combination of the verification methods listed in Table 2 shall be applied to verify that the safety requirements comply with the requirements in this clause and that they comply with the specific requirements on the verification of safety requirements within the respective parts of ISO 26262 where safety requirements are derived

Table 2 — Methods for the verification of safety requirements

Methods		ASIL			
		A	B	C	D
1a	Verification by walk-through	++	+	o	O
1b	Verification by inspection	+	++	++	++
1c	Semi-formal verification[a]	+	+	++	++
1d	Formal verification	o	+	+	+

[a] Method 1c can be supported by executable models.

ISO 26262 – 8 : 2011

7 Configuration Management

- Objectives
  - ensure that the work products, and the principles and general conditions of their creation, can be uniquely identified and reproduced in a controlled manner at any time
  - ensure that the relations and differences between earlier and current versions can be traced

- General
  - Configuration management is a well established practice within the automotive industry and can be applied according to ISO/TS 16949, ISO 10007 and ISO/IEC 12207
  - Each work product of ISO 26262 is managed by configuration management

  - **Configuration management** (CM) is a process for establishing and maintaining consistency of a product's performance, functional and physical attributes with its requirements, design and operational information throughout its life

7 Configuration Management (Requirements and Recommendations)

- The configuration management process shall comply with:
  - the respective requirements of a quality management system (e.g. ISO/TS 16949, or ISO 9001)
  - the specific requirements for software development according to the clause on configuration management in ISO/IEC 12207
  - The work products required by the safety plan in accordance with ISO 26262-2 shall be placed under configuration management and baselined according to the configuration management strategy
  - Work products placed under configuration management shall be documented in the configuration management plan
  - Configuration management shall be maintained throughout the entire safety lifecycle

8 Change Management

- Objectives
  - analyze and control changes to safety-related work products throughout the safety lifecycle

- General
  - Change management ensures the systematic planning, control, monitoring, implementation and documentation of changes
  - maintaining the consistency of each work product
  - Potential impacts on functional safety are assessed before changes are made
  - decision-making processes for change are introduced and established, and responsibilities are assigned to the parties involved

8 Change Management (Requirements and Recommendations)

- Planning and initiating change management
  - The change management process shall be planned and initiated, before changes are made to work products
  - The work products to be subject to change management shall be identified and shall include those work products required by ISO 26262 to be placed under configuration management
  - The schedule for applying the change management process shall be defined for each work product
  - The change management process shall include:
    - the change requests in accordance with 8.4.2,
    - the analysis of change requests in accordance with 8.4.3,
    - the decision and rationale regarding change requests in accordance with 8.4.4,
    - the implementation of the accepted changes in accordance with 8.4.5, and
    - the documentation in accordance with 8.4.5
- Change requests
  - A unique identifier shall be assigned to each change request
  - As a minimum, every change request shall include the following information:
    - the date,
    - the reason for the requested change,
    - the exact description of the requested change, and
    - the configuration on which the requested change is based

8 Change Management (Requirements and Recommendations)

- Change request analysis
  - An impact analysis on the item involved, its interfaces and connected items, shall be carried out for each change request. The following shall be addressed
    - the type of change request,
      NOTE: Possible types of changes include: error resolution, adaptation, enhancement, prevention.
    - the identification of the work products to be changed and the work products affected,
    - the identification and involvement of the parties affected, in the case of a distributed development,
    - the potential impact of the change on functional safety
    - the schedule for the realization and verification of the change
  - Each change to work products shall initiate the return to the applicable phase of the safety lifecycle. Subsequent phases shall be carried out in compliance with ISO 26262

- Change request evaluation
  - The change request shall be evaluated using the results of the impact analysis in compliance with 8.4.3.1[Change request analysis] and a decision regarding acceptance, rejection or delay shall be made by the authorized persons
  - For each accepted change request it shall be decided who shall carry out the change and when the change is due. This decision shall consider the interfaces involved in carrying out the change request

- Carrying out and documenting the change
  - The changes shall be carried out and verified as planned
  - If the change has an impact on safety-related functions, the assessment of functional safety and the applicable confirmation reviews, in accordance with ISO 26262-2:2011, 6.4.7 and 6.4.9, shall be updated before releasing the item.
  - The documentation of the change shall contain the following information:
    - the list of changed work products at an appropriate level including configurations and versions
    - the details of the change carried out
    - the planned date for the deployment of the change

9 Verification

- Objectives
  - ensure that the work products comply with their requirements
- General
  - Verification is applicable to the following phases of the safety lifecycle.
    - In the concept phase, verification ensures that the concept is correct, complete and consistent with respect to the boundary conditions of the item, and that the defined boundary conditions themselves are correct, complete and consistent, so that the concept can be realized
    - In the product development phase, verification is conducted in different forms
      - In the design phases, verification is the evaluation of the work products
      - In the test phases, verification is the evaluation of the work products within a test environment to ensure that they comply with their requirements
    - In the production and operation phase, verification ensures that:
      - the safety requirements are appropriately realized in the production process, user manuals and repair and maintenance instructions
      - the safety-related properties of the item are met by the application of control measures within the production process

9 Verification (Requirements and Recommendations)

- Verification planning
  - The verification planning shall be carried out for each phase and sub-phase of the safety lifecycle and shall address the following:
    - the content of the work products to be verified
    - the methods used for verification
    - the pass and fail criteria for the verification,
    - the verification environment, if applicable
    - the tools used for verification, if applicable,
    - the actions to be taken if anomalies are detected, and
    - the regression strategy

      NOTE A regression strategy specifies how verification is repeated after changes have been made to the item or element. Verification can be repeated fully or partially and can include other items or elements that might affect the results of the verification
  - The planning of verification should consider the following:
    - the adequacy of the verification methods to be applied
    - the complexity of the work product to be verified
    - prior experiences related to the verification of the subject material

      NOTE This includes service history as well as the degree to which a proven in use argument has been achieved
    - the degree of maturity of the technologies used, or the risks associated with the use of these technologies

9 Verification (Requirements and Recommendations)

- Verification Specification
  - The verification specification shall select and specify the methods to be used for the verification, and shall include:
    - review or analysis checklists
    - simulation scenarios
    - test cases, test data and test objects
  - For testing, the specification of each test case shall include the following:
    - a unique identification,
    - the reference to the version of the associated work product to be verified
    - the preconditions and configurations
    - the environmental conditions, if appropriate
    - the input data, their time sequence and their values
    - the expected behavior which includes output data, acceptable ranges of output values, time behavior and tolerance behavior
  - For testing, test cases shall be grouped according to the test methods to be applied. For each test method, in addition to the test cases, the following shall be specified:
    - the test environment
    - the logical and temporal dependencies
    - the resources
- Verification execution and evaluation
  - The evaluation of the verification results shall contain the following information:
    - the unique identification of the verified work product,
    - the reference to the verification plan and verification specification,
    - the configuration of the verification environment and verification tools used, and the calibration data used during the evaluation, if applicable,
    - the level of compliance of the verification results with the expected results,
    - an unambiguous statement of whether the verification passed or failed; if the verification failed the statement shall include the rationale for failure and suggestions for changes in the verified work product, and
    - the reasons for any verification steps not executed

ISO 26262 – 8 : 2011

10 Documentation

- Objectives
  - develop a documentation management strategy for the entire safety lifecycle in order to facilitate an effective and repeatable documentation management process

- General
  - The documentation requirements in ISO 26262 focus mainly on information, and not on layout and appearance
  - The information need not be made available in physical documents, unless explicitly specified by ISO 26262. The documentation can take various forms and structures and tools can be used to generate documents automatically
  - Duplication of information within a document, and between documents, should be avoided to aid maintainability

    NOTE: An alternative to duplicating information is the use of a cross-reference within one document, directing the reader to the information source document

10 Documentation (Requirements and Recommendations)

- The documentation process shall be planned in order to make documentation available:
  - during each phase of the entire safety lifecycle for the effective completion of the phases and verification activities,
  - for the management of functional safety, and
  - as an input to the functional safety assessment
- The identification of a work product in ISO 26262 shall be interpreted as a requirement for documentation containing the information concerning the results of the associated requirements.
- The documents should be:
  - precise and concise,
  - structured in a clear manner,
  - easy to understand by the intended users, and
  - maintainable.
- The structure of the entire documentation should consider in-house procedures and working practices. It shall be organized to facilitate the search for relevant information
- Each work product or document shall be associated with the following formal elements:
  - the title, referring to the scope of the content,
  - the author and approver,
  - unique identification of each different revision (version) of a document,
  - the change history
  - the status.
- It shall be possible to identify the current applicable revision (version) of a document or item of information

11 Confidence in the use of Software Tools

- Objectives
  - provide criteria to determine the required level of confidence in a software tool when applicable
  - provide the qualification of the software tool when applicable, in order to create evidence that the software tool is suitable to be used to tailor the activities or tasks required by ISO 26262 (i.e. the user can rely on the correct functioning of a software tool for those activities or tasks required by ISO 26262)
- General
  - A software tool used in the development of a system or its software or hardware elements, can support or enable a tailoring of the safety-lifecycle, through the tailoring of activities and tasks required by ISO 26262. In such cases confidence is needed that the software tool effectively achieves the following goals:
    - the risk of systematic faults in the developed product due to malfunctions of the software tool leading to erroneous outputs is minimized, and
    - the development process is adequate with respect to compliance with ISO 26262, if activities or tasks required by ISO 26262 rely on the correct functioning of the software tool used.

NOTE The understanding of "software tool" can vary from a separately usedstand-alone software tool to a set of software tools integrated into a tool-chain

11 Confidence in the use of Software Tools (Requirements and Recommendations)

- General Requirement
  - If the safety lifecycle incorporates the use of a **software tool for the development** of a system, or its **hardware** or **software elements**, such that activities or tasks required by ISO 26262 rely on the **correct functioning of a software tool**, and where the relevant outputs of that tool are not examined or verified for the applicable process step(s), such software tools shall comply with the requirements of this clause.

  - When using a software tool, it shall be ensured that its usage, its determined environmental and functional constraints and its general operating conditions comply with its evaluation criteria or its qualification

    EXAMPLE Use of identical version and configuration settings for the same use cases together with the same implemented measures for the prevention or detection of malfunctions and their corresponding erroneous output, as documented in the qualification report for this software tool.

  - The usage of a software tool shall be planned, including the determination of:
    - the identification and version number of the software tool,
    - the configuration of the software tool
      EXAMPLE The configuration of a compiler is defined by setting compiler switches and "#pragma" statements in a C source file.
    - the use cases of the software tool
    - the environment in which the software tool is executed
    - the maximum ASIL of all the safety requirements, allocated to the item or the element that can be violated,
    - if the software tool is malfunctioning and producing corresponding erroneous output
    - the methods to qualify the software tool, if required based on the determined level of confidence

ISO 26262 – 8 : 2011

11 Confidence in the use of Software Tools (Requirements and Recommendations)

- Validation of the software tool
  - The validation of the software tool shall meet the following criteria:
    - the validation measures shall demonstrate that the software tool complies with its specified requirements
    - the malfunctions and their corresponding erroneous outputs of the software tool occurring during validation shall be analyzed together with information on their possible consequences and with measures to avoid or detect them
    - the reaction of the software tool to anomalous operating conditions shall be examined

12 Qualification of software components

- Objective
  - provide evidence for their suitability for re-use in items developed in compliance with ISO 26262
- General
  - The re-use of qualified software components avoids re-development for software components with similar or identical functionality

    NOTE Software components are understood to include source code, models, pre-compiled code, or compiled and linked software

  - To be able to consider a software component as qualified, the following shall be available:
    - the specification of the software component
    - evidence that the software component complies with its requirements
    - evidence that the software component is suitable for its intended use
    - evidence that the software development process for the component is based on an appropriate national or international standard
  - The planning of qualification of a software component shall determine:
    - the unique identification of the software component
    - the maximum target ASIL of any safety requirement which might be violated if the software component performs incorrectly
    - the activities that shall be carried out to qualify the software component

12 Qualification of software components (Requirements and Recommendations)

- Qualification of a software component. The specification of the software component shall include:
  - the requirements of the software component
  - the description of the configuration
  - the description of interfaces
  - the application manual, where appropriate
  - the description of the software component integration
  - the reactions of the functions under anomalous operating conditions
  - the dependencies with other software components
  - a description of known anomalies with corresponding work-around measures
- To provide evidence that a software component complies with its requirements the verification of this software component shall
  - show a requirement coverage in accordance with ISO 26262-6:2011
  - cover both normal operating conditions and behavior in the case of failure
  - result in no known errors that lead to violation of safety requirements

13 Qualification of hardware components

- Objective
  - provide evidence of the suitability of intermediate level hardware components and parts for their use as part of items, systems or elements, developed in compliance with ISO 26262, concerning their functional behavior and their operational limitations for the purposes of the safety concept
  - provide relevant information regarding:
    - their failure modes,
    - their failure mode distribution, and
    - their diagnostic capability with respect to the safety concept for the item.
- General
  - **Every safety-related hardware component and part used within the scope of ISO 26262 is subject to standard qualification** to address general functional performance, conformity of production, environmental endurance and robustness.
  - For basic parts (passive component, discrete semiconductor), standard qualification is sufficient. These basic parts can then be used in a hardware design in accordance with ISO 26262-5
  - The requirements of this clause apply to intermediate level hardware components or parts, which provide dedicated functionality to the system

13 Qualification of hardware components (Requirements and Recommendations)

- The relevant failure modes of the component or part to be qualified shall be assumed to be verifiable by testing, analysis or both

  - The qualification of the hardware component or part shall be carried out using an appropriate selection of the following methods:
    - Analyses
    - Testing

  - A qualification plan shall be developed and shall describe:
    - precise identification and version of the hardware component or part
    - specification of the environment in which the hardware component or part is intended to be used
    - the qualification strategy and the rationale
    - the necessary tools and equipment enabling this strategy
    - the party responsible for carrying out this strategy
    - the criteria used to assess the qualification of a hardware component or part as passed or failed

  - Qualification by analyses
    - The analysis shall be expressed in a form that can be easily understood and checked by persons who are qualified in the relevant engineering or scientific disciplines
    - The analyses shall consider all the environmental conditions to which the hardware component or part is exposed, the limits of these conditions and, other additional strains related to operation (e.g. expected switch cycles, charging and discharging, long turn-off times)

13 Qualification of hardware components (Requirements and Recommendations)

- Qualification by Testing
  - A test plan shall be developed and shall contain the following information:
    - description of the functions of the hardware component or part
    - number and sequence of tests to be conducted
    - requirements for assembly and connections
    - procedure for accelerated ageing, considering the operating conditions of the hardware component or part
    - operating and environmental conditions to be simulated
    - pass/fail criteria to be established
    - environmental parameters to be measured
    - requirements for the testing equipment, including accuracy
    - maintenance and replacement processes permitted during the testing
  - The test shall be conducted as planned and the resulting test data shall be made available

- Qualification report
  - The qualification report shall state whether the hardware component or part has passed or failed the qualification with respect to the operating envelope.
  - The qualification report shall be verified in accordance with Clause 9

14 Proven in Use Argument

- Objectives
  - provides guidance for a proven in use argument. A proven in use argument is an alternate means of compliance with ISO 26262 that may be used in the case of reuse of existing items or elements when field data is available
- General
  - A proven in use argument can be applied to any type of product whose definition and conditions of use are identical to or have a very high degree of commonality with a product that is already released and in operation.
  - It can also be applied to any work product related to such products.

14 Proven in Use Argument

- Proven in use argument relies on:
  - The relevance of field data during the service period of the candidate to a proven in use argument
  - A disciplined configuration management and change control of the product during and after its service period

- An item or an element, such as system, function, hardware or software product, can be a **candidate** for a proven in use argument.
- A **candidate** can also refer to system, hardware or software work products such as a technical safety concept, algorithms, models, source code, object code, software components, a set of configurations or calibration data.

14 Proven in Use Argument

- The motivation for using the argument for proven in use includes:
  - an automotive application in commercial use intended to be partly or completely carried over to another target
  - an ECU in operation intended to implement an additional function
  - a candidate being in the field prior to the release of ISO 26262
  - a candidate being used in other safety-related industries
  - a candidate being a widely used COTS product not necessarily intended for automotive applications.

- Once a candidate has been defined with the expected proven in use credit, two important criteria need to be considered when preparing a proven in use argument:
  - the relevance of field data during the service period of the candidate
  - the changes, if any, that could have impacted the candidate since its service period

14 Proven in Use Argument

(Minimum information on candidate)

- A description of the candidate and its previous use shall be available, that includes:
  - the identification and traceability of the candidate with a catalogue of internal elements or components
  - the corresponding fit, form and function requirements that describe, if applicable, interface and environmental, physical and dimensional, functional and performance characteristics of the candidate
  - the safety requirements of the candidate in the previous use and the corresponding ASILs
- Proven in use candidates (Changes)
  - Changes to candidates address design changes and implementation changes
  - Design changes can result from modification of requirements, functional enhancements or performance enhancement
  - Implementation changes do not affect specification or performances of the candidate but only its implementation features
  - Implementation changes can result from software corrections or use of new development or production tools
  - Changes to configuration data or calibration data are considered as changes to the candidate when they impact its behavior with regard to the violation of the safety goals

14 Proven in Use Argument

14 Proven in Use Argument

DIA (Development Interface Agreement) Example

- Many factors will affect the type and amount of customer-supplier interactions

- The DIA example follows this application scenario:
  - The customer is responsible for engineering and manufacturing the vehicle
  - The customer is responsible for engineering the system comprised of many hardware and software components of which one hardware component C, is to be sourced from some supplier
  - Component C will be allocated requirements with assigned ASIL D
  - Component C has not been developed previously, i.e., it is not a commercial off-the-shelf (COTS) product. It involves new technology for which there is an inadequate pool of proven suppliers
  - Multiple suppliers are interested in the supply of Component C, but adequate capability to support the project is not evident
  - A model-based development process is used

- This example is developed on the following premises:
  - Resources required for project management and engineering are available when needed
  - Assessment teams that qualify as "independent" are available to each participating organization, and are used where needed
  - The same process and architectural framework is in use in all the participating organizations, independently assessed to qualify for the highest integrity level

DIA Example

Table B.1 — Customer-supplier data exchanges to qualify and select supplier

ID	Activity	Data from customer to supplier	Data from supplier to customer
A.1	Pre-qualify[a] suppliers; project independent criteria; feeds into 5.4.2	Capability assessment questionnaire[a]: — safety culture (ISO 26262-2:2011, 5.4.2); — evidence of competence (ISO 26262-2:2011, 5.4.3; — evidence of quality management (ISO 26262-2:2011, 5.4.4); — ISO 26262 Consent, e.g.: — independent assessment (5.4.5); — DIA template	—
A.2		—	Acceptance of conditions[a]
A.3		—	Capability assessment[a] (ISO 26262-2:2011, Clause 5) Disclosure[a] Corrective action proposed[a]
A.4		Evaluation: ASILs for which not qualified[a]	—
A.5	Qualify suppliers (short-list)[a] 5.4.2	Customer-organization-specific process adaptation of ISO 26262-2:2011, 5.4.5 incl. methods, languages, tools & usage constraints/guidelines.	—
		—	1st party assessment of compliance. Disclosure[a] Track record (5.4.2.1). Corrective action proposed[a] Alternative approach or proposal to meet objectives[a]
		Iterative evaluation & enquiries about gaps and alternatives[a]	Iterative revisions to plans and alternatives[a]
		Evaluation: ASILs for which not qualified[a]	—

DIA Example

Table B.1 — Customer-supplier data exchanges to qualify and select supplier

ID	Activity	Data from customer to supplier	Data from supplier to customer
A.6	Invite proposal 5.4.2.2	RFP/RFQ, including project-specific tailored process [5.4.3.1 b)], product concept i.e. item definition (ISO 26262-3:2011, 5.5) and safety goals (ISO 26262-3:2011, 7.5.2).	—
A.7	—	—	Offer; Statement of compliance; Updates to previously submitted information[a]
A.8	Select supplier 5.4.2	Proposed DIA (project-specific) 5.4.3	—
A.9		—	Selected project resources and their capability assessment, e.g. safety team members' skills, competencies and qualification (ISO 26262-2:2011, 5.5.2); Organization-specific rules and processes (ISO 26262-2:2011, 5.5.1), incl. tools, libraries; Preliminary plans, e.g. safety plan (ISO 26262-2:2011, 6.5.1)
A.10		Iterative evaluation and enquiries, e.g. regarding skill gaps[a]	Iterative revisions addressing customer concerns[a]
A.11		Acceptance of DIA. (5.5.2) Selection report (5.5.1)	Acceptance of DIA (5.5.2)
A.12		Contract for concept (ISO 26262-3; ISO 26262-4) and planning phase (ISO 26262-4:2011, Clause 5) incl. statement of development work.	Acceptance.

[a] Activity or data which is organization-specific and is not required in ISO 26262.

DIA Example

Table B.2 — Customer-supplier data exchanges in project initiation and system concept

ID	Activity	Data from customer to supplier	Data from supplier to customer
B.1	Initiate project (5.4.3) Create functional safety concept (ISO 26262-3:2011, Clauses 5 to 8)	System level plans Item definition (ISO 26262-3:2011, 5.5) and its lifecycle (Figure 1, ISO 26262-2:2011, 5.2.2; ISO 26262-2:2011, Figure 2 and ISO 26262-2:2011, 6.4.5) Functional safety concept (ISO 26262-3:2011, Clause 8)	—
B.2	—	—	Project plan (5.5.3) Safety plan (5.5.4) H&R analysis (5.4.3.2), hardware component behaviour models, incl. fault metrics [5.4.3.1 f), ISO 26262-5:2011, Annex B, and ISO 26262-5:2011, 9.4.3.1]. Independent assessment of plans, incl. assurance that processes and resources are configured and allocated to match the required work products, incl. skill-sets. [5.4.3 c) e), g), 5.4.5]
B.3	—	Acceptance	—
B.4	Consideration of experience gained from proven in use components, tools, libraries used in similar projects (5.4.4.5), as well as proven in use data and analyses of possible candidates (ISO 26262-8:2011, Clause 14)	Initial safety plan (ISO 26262-2:2011, Clause 5), incl. system safety case structure	—
B.5	—	—	Proven in use elements offered (Clause 14), with independent assessment of fitness for the project (5.4.5 and ISO 26262-2:2011, Table 1)
B.6	—	Acceptance	—
B.7	System development lifecycle [5.4.3 b)]	Technical safety concept (ISO 26262-4:2011, 7.5.1), relevant parts of system design specs, hardware specs, design & implementation (D&I) constraints, hardware-software Interface (HSI) specifications (ISO 26262-4:2011, 7.5.3).	Iterative evaluation, clarification-queries, and feedback about conflicts, completeness, consistency, etc.; technological limitations, if any; change requests, if any (5.4.4). Updated behaviour models, incl. fault models.
B.8		Iterative clarifications, responses, and revisions, including updates to system architecture design & verification specifications (ISO 26262-4:2011, 7.5.2, ISO 26262-4:2011, 7.5.5), hardware specifications (ISO 26262-5:2011, 7.5.1) relevant to Component C, HSI, allocation, etc.	Feedback about boundary between Component C & its environment.
B.9	—	—	Acceptance

DIA Example

Table B.3 — Customer-supplier data exchanges in hardware development lifecycle

ID	Activity	Data from customer to supplier	Data from supplier to customer
C.1	Plan (5.4.3)	Authorisation for hardware development	-
C.2		—	Plans: Safety plan (5.5.4 and ISO 26262-5:2011, 5.5.1), Project plan (5.5.3 and ISO 26262-5:2011, 5.5.2), item integration and testing plan (see ISO 26262-4:2011, 5.5.3), planning of DIA (5.4.3) etc. Independent reviews of conformance to planning (5.4.4.8 and 5.4.5).
C.3		Acceptance. Authorisation to commence requirements specification.	—
C.4	Requirements (5.4.5 and ISO 26262-5)	—	hardware specifications - derived; refined; D&I constraints (ISO 26262-5:2011, 7.5.1). Extension to Verification Plan[a] HSI change requests, if any (ISO 26262-5:2011, 10.5). Independent safety audit (5.4.4.8) Independent confirmation (5.4.5 and 5.5.5).
C.5	—	Acceptance. Authorisation to commence design.	—
C.6	Design (5.4.5, and ISO 26262-5)	—	Design specs (ISO 26262-5:2011, 7.5.1); implementation constraints, incl. architectural (ISO 26262-5:2011, Clause 8). Extension or modification to H&R analysis (ISO 26262-3:2011, Clause 7), if any. Extension to item integration and testing plan (ISO 26262-5:2011, 10.5). HSI change requests, if any (ISO 26262-5:2011, 10.5). Independent safety audit (5.4.4.8, 5.4.5)

DIA Example

Table B.3 — Customer-supplier data exchanges in hardware development lifecycle

ID	Activity	Data from customer to supplier	Data from supplier to customer
C.7	5.4.4 and 5.4.5	Iterative evaluation and feedback concerning conflicts discovered at system level.	Iterative clarifications, revisions, and other responses addressing customer feedback and enquiries. Independent assessment (5.4.5 and 5.5.5).
C.8	5.4.4 and 5.4.5	Acceptance of component design. Authorisation to implement.	Implementation. Requirements from the environment. Independent assessment (5.4.5 and 5.5.5).
C.9	—	Acceptance	—
C.10	—	—	Prototype part Integrated verification (ISO 26262-5:2011, 10.5) Independent assessment (5.4.5).
C.11	—	Integrated evaluation (ISO 26262-4:2011, Clause 8). Change requests, if any.	—
C.12	—	—	Reviews & audits of processed changes Independent assessment (5.4.5, 5.5.5).
C.13	—	Acceptance	—
C.14	—	—	Sample for series production Independent assessment (5.4.5, 5.5.5).
C.15	—	Integrated evaluation (ISO 26262-4:2011, Clause 8) Change requests, if any.	—
C.16	—	—	Reviews & audits of processed changes Independent assessment (5.4.4, 5.4.5 and 5.5.5).
C.17	—	Authorisation for commencing production phase	—
C.18	—	—	Post-SOP reports (5.4.6 and 5.5.6 and ISO 26262-2:2011, 7.5).

[a] Activity or data which is organization-specific and is not required in ISO 26262.

ISO 26262 – 9 : 2011
Automotive Safety Integrity Level(ASIL) - oriented and safety-oriented analyses

5 Requirements decomposition with respect to ASIL tailoring

- Objective
  - Provides rules and guidance for decomposing safety requirements into redundant safety requirements to allow ASIL tailoring at the next level of detail

- General
  - The ASIL of the safety goals of an item under development is propagated throughout the item's development process. Starting from safety goals, the safety requirements are derived and refined during the development phases. The ASIL, as an attribute of the safety goal, is inherited by each subsequent safety requirement. The functional and technical safety requirements are allocated to architectural elements, starting with preliminary architectural assumptions and ending with the hardware and software elements
  - The method of **ASIL tailoring during the design process is called "ASIL decomposition"**. During the allocation process, benefit can be obtained from architectural decisions including the existence of sufficiently independent architectural elements. This offers the opportunity:
    - to implement safety requirements redundantly by these independent architectural elements, and
    - to assign a potentially lower ASIL to these decomposed safety requirement

5 Requirements decomposition with respect to ASIL tailoring

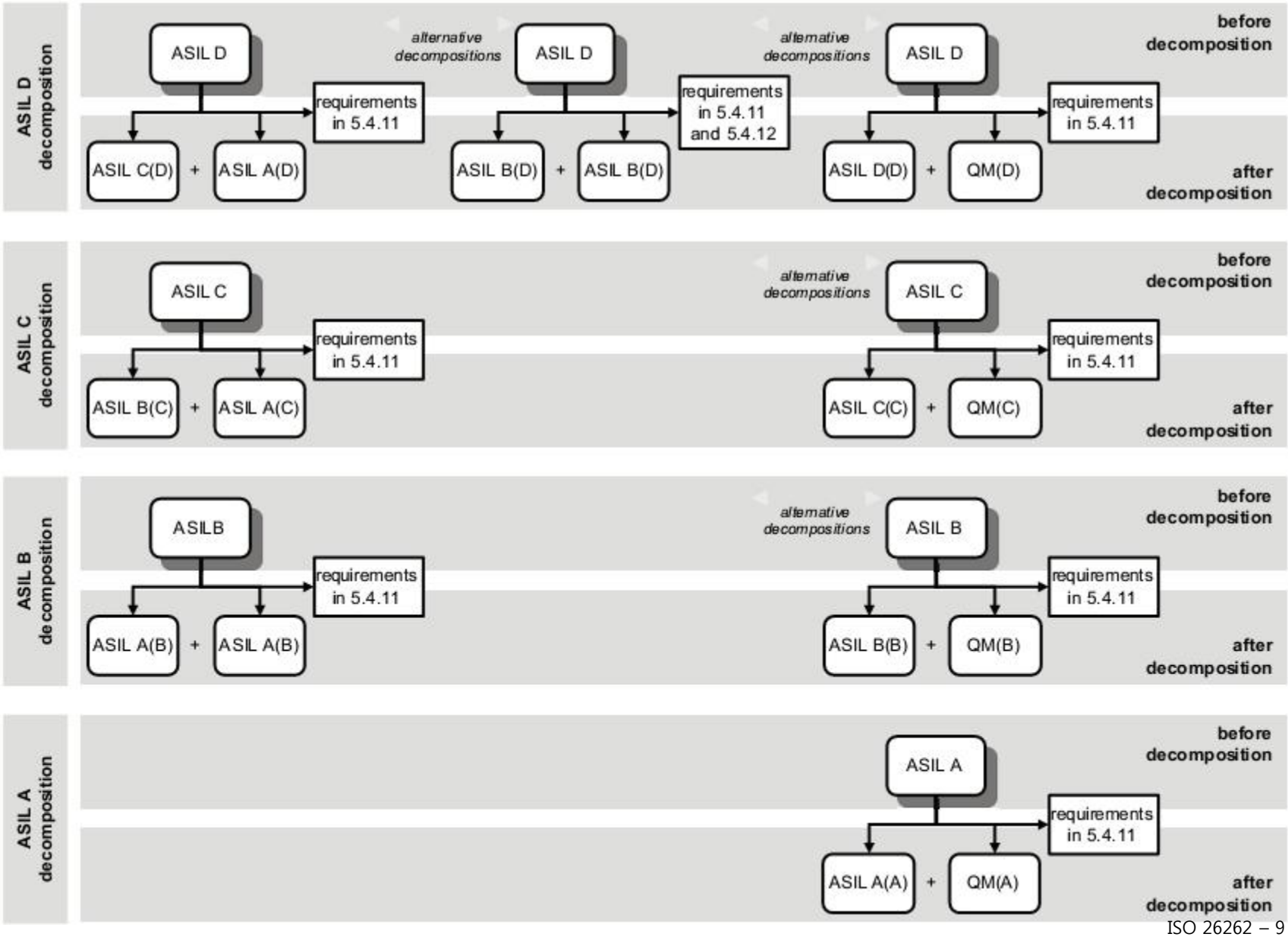
(Requirements and recommendations)

- If ASIL decomposition is applied, all the requirements within this clause shall be complied with
- ASIL decomposition shall be performed by considering each initial safety requirement individually
- The initial safety requirement shall be decomposed to redundant safety requirements implemented by sufficiently independent elements
- Each decomposed safety requirement shall comply with the initial safety requirement by itself
- The requirements on the evaluation of the hardware architectural metrics and the evaluation of safety goal violations due to random hardware failures shall remain unchanged by ASIL decomposition in accordance with ISO 26262-5

- If an **ASIL D requirement** is **decomposed into** one **ASIL C** requirement and one **ASIL A** requirement, then these are marked as **"ASIL C(D)" and "ASIL A(D)".** If the ASIL C(D) requirements further decomposed into one ASIL B requirement and one ASIL A requirement, then these are also marked with the ASIL of the safety goal as "ASIL B(D)" and "ASIL A(D)"

5 Requirements decomposition with respect to ASIL tailoring

(ASIL Decomposition Schemes)



ISO 26262 – 9 : 2011

6 Criteria for coexistence of elements

- Objective
  - Provides criteria for the coexistence within the same element of:
    - safety-related sub-elements with sub-elements that have no ASIL assigned; and
    - safety-related sub-elements that have different ASILs assigned.
- General
  - When an element is composed of several sub-elements, each of those sub-elements is developed in accordance with the measures corresponding to the highest ASIL applicable to the element
  - In the case of the coexistence of sub-elements that have different ASILs assigned or the coexistence of sub-elements that have no ASIL assigned with safety-related ones, it can be beneficial to avoid raising the ASIL for some of them to the ASIL of the element
  - Interference is the presence of cascading failures from a sub-element with no ASIL assigned, or a lower ASIL assigned, to a sub-element with a higher ASIL assigned leading to the violation of a safety requirement of the element

7 Analysis of dependent failures

- Objective
  - The analysis of dependent failures aims to identify the single events or single causes that could bypass or invalidate a required independence or freedom from interference between given elements and violate a safety requirement or a safety goal.

- General
  - The analysis of dependent failures considers architectural features such as:
    - similar and dissimilar redundant elements
    - different functions implemented with identical software or hardware elements
    - functions and their respective safety mechanisms
    - partitions of functions or software elements
    - physical distance between hardware elements, with or without barrier
    - common external resources

8 Safety Analyses

- Objective
  - The objective of safety analyses is to examine the consequences of faults and failures on the functions, behavior and design of items and elements. Safety analyses also provide information on conditions and causes that could lead to the violation of a safety goal or safety requirement
  - Additionally, the safety analyses also contribute to the identification of new functional or non-functional hazards not previously identified during the hazard analysis and risk assessment

- General
  - The scope of the safety analyses includes:
    - the validation of safety goals and safety concepts
    - the verification of safety concepts and safety requirements
    - the identification of conditions and causes, including faults and failures, that could lead to the violation of a safety goal or safety requirement
    - the identification of additional requirements for detection of faults or failures
    - the determination of the required responses (actions/measures) to detected faults or failures
    - the identification of additional requirements for verifying that the safety goals or safety requirements are complied with, including safety-related vehicle testing

The END !!!